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Nuclear Data Sheets 160 (2019) 405–471
Nuclear Data Sheets
www.elsevier.com/locate/nds

Nuclear Data Sheets for A=218

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(Received 29 March 2019; Revised 17 September 2019)

Abstract: The evaluated data are presented for 11 known A=218 nulcides (Pb, Bi, Po, At, Rn, Fr, Ra, Ac, Th, Pa and U). For ^{218}Pb, ^{218}Bi, ^{218}At and ^{218}Pa, data are available only for the ground states. For ^{218}U, only the g.s. and a high-spin isomer are known, with no data on γ-ray transitions available. For ^{218}Po, ten excited states are known from ^{218}Bi decay, with no knowledge on the multipolarities of gamma-ray transitions. For ^{218}Th, five excited states in the g.s. band are known from an in-beam γ-ray study. Data on level half-lives, multipolarities and mixing ratios of gamma transitions is generally lacking for A=218 nuclei. The static magnetic dipole moment has been measured for only an isomer in ^{218}Fr. With the exception of a new nuclide, ^{218}Pb, and measurements of half-lives of ground states of a few nuclides of A=218 and A=222, no substantial structure information has become available since the previous evaluation in 2006. Q values are adopted from 2017Wa10 (AME-2016). The present evaluation supersedes the previous A=218 ENSDF evaluations, 2006Ja03, 1995El08, 1987El12 and 1977To13. This evaluation was carried out as part of a joint IAEA-ICTP workshop for Nuclear Structure and Decay Data, organized and hosted by the IAEA, Vienna, and ICTP, Trieste, October 15-26, 2018.

Cutoff Date: All data received prior to October 30, 2019 have been considered. The main source of bibliographic search was the NSR database (2011Pr03) available at NNDC, BNL webpage: www.nndc.bnl.gov/nsr/.

General Policies and Organization of Material: See the January issue of the *Nuclear Data Sheets* or http://www.nndc.bnl.gov/nds/NDSPolicies.pdf.

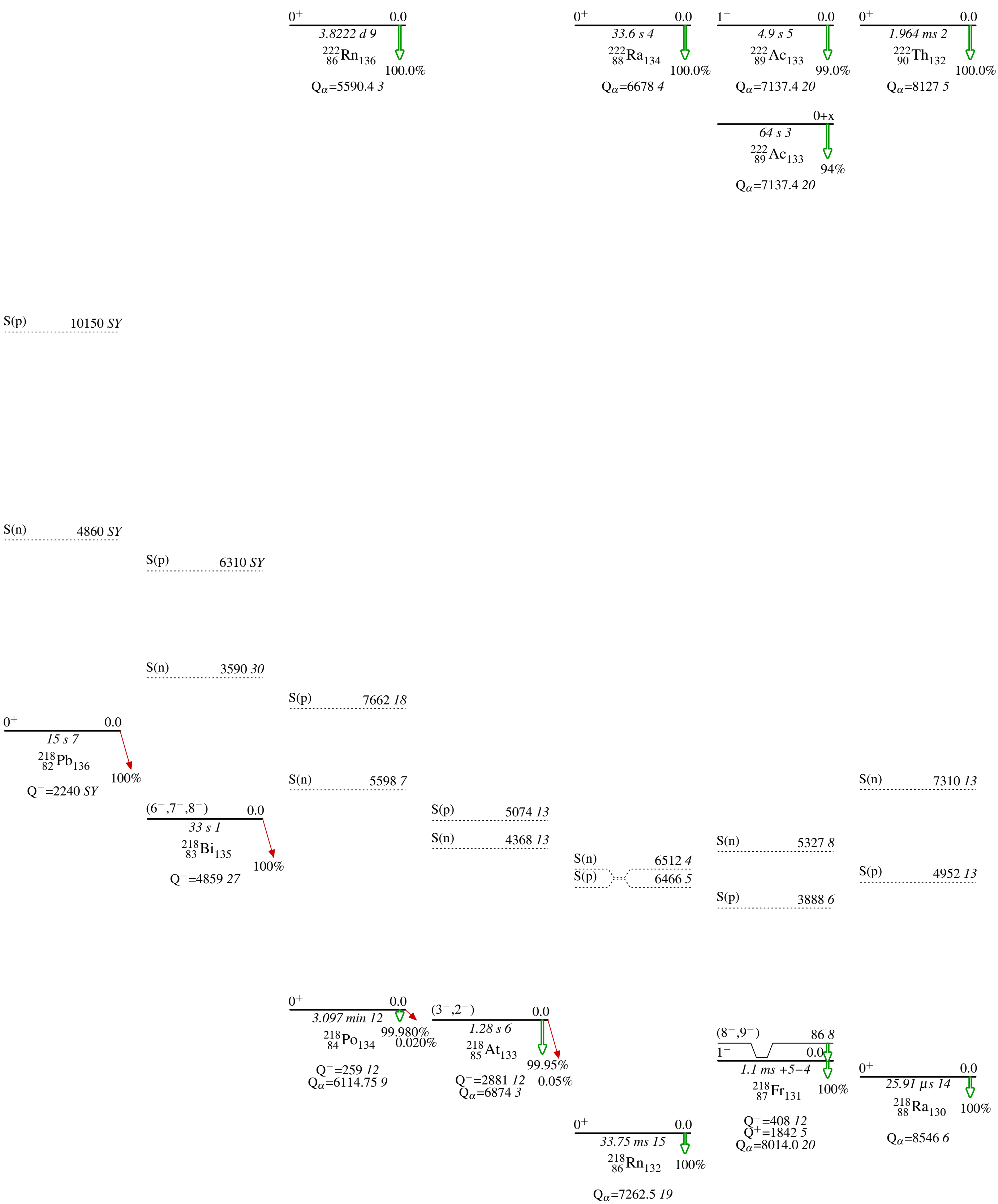
General Comments: Theoretical conversion coefficients from BrIcc code (2008Ki07) have an implied uncertainty of 1.4%, when not stated. In the averaging procedure, the recommended uncertainty is generally not below the lowest experimental uncertainty in a set of data points.

Acknowledgements: We thank J. Totans (BNL) for sending us copies of several articles. We are grateful to P. Dimitriou (IAEA-NDS) for overall coordination of the workshop, and to J.K. Tuli for a review of this evaluation. Work supported by the IAEA, Vienna; ICTP, Trieste; and the Office of Science, U.S. Department of Energy under contracts: DE-AC02-98CH10946 (BNL), DE-AC02-05CH11231 (LBNL), and DE-AC02-98CH10886 (ORNL).

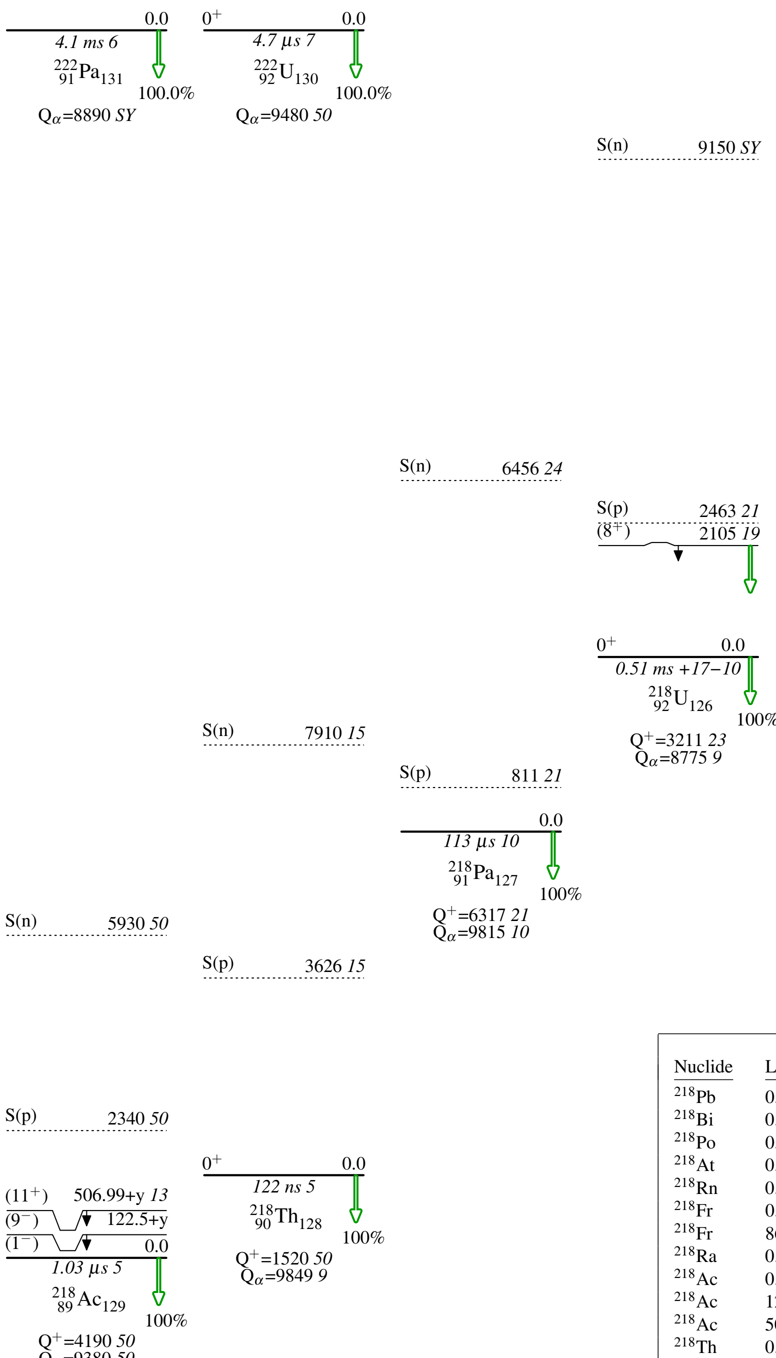
https://doi.org/10.1016/j.nds.2019.100524
0090-3752/

Index for A=218

Skeleton Scheme for A=218



Skeleton Scheme for A=218 (continued)



Ground-State and Isomeric-Level Properties

Nuclide	Level	Jπ	$T_{1/2}$	Decay Mode
^{218}Pb	0.0	0^+	15 s *7*	%β^-=100
^{218}Bi	0.0	$(6^-,7^-,8^-)$	33 s *1*	%β^-=100
^{218}Po	0.0	0^+	3.097 min *12*	%α=99.980 *2*; %β^-=0.020 *2*
^{218}At	0.0	$(3^-,2^-)$	1.28 s *6*	%α=99.95 *5*; %β^-=0.05 *5*
^{218}Rn	0.0	0^+	33.75 ms *15*	%α=100
^{218}Fr	0.0	1^-	1.1 ms *+5−4*	%α=100
^{218}Fr	86	$(8^-,9^-)$	21.9 ms *5*	%α≈100
^{218}Ra	0.0	0^+	25.91 μs *14*	%α=100
^{218}Ac	0.0	(1^-)	1.03 μs *5*	%α=100
^{218}Ac	122.5+y	(9^-)	32 ns *9*	%IT=100
^{218}Ac	506.99+y	(11^+)	103 ns *11*	%IT=100
^{218}Th	0.0	0^+	122 ns *5*	%α=100
^{218}Pa	0.0		113 μs *10*	%α=100
^{218}U	0.0	0^+	0.51 ms *+17−10*	%α=100
^{218}U	2105	(8^+)	0.56 ms *+26−14*	%α=?; %IT=?
^{222}Rn	0.0	0^+	3.8222 d *9*	%α=100.0
^{222}Ra	0.0	0^+	33.6 s *4*	%α=100.0
^{222}Ac	0.0	1^-	4.9 s *5*	%α=99.0 *10*
^{222}Ac	0+x		64 s *3*	%α=94 *6*
^{222}Th	0.0	0^+	1.964 ms *2*	%α=100.0
^{222}Pa	0.0		4.1 ms *6*	%α=100.0
^{222}U	0.0	0^+	4.7 μs *7*	%α=100.0

Adopted Levels

Q(β^-)=2240 *SY*; S(n)=4860 *SY*; S(p)=10150 *SY*; Q(α)=1850 *SY* 2017Wa10

Estimated uncertainties (2017Wa10): 300 for Q(β^-), 420 for S(n), 500 for S(p) and Q(α).

S(2n)=8170 *360*, S(2p)=18980 *500* (syst,2017Wa10).

2010Al24 (also 2009Al32): ^{218}Pb nuclide identified in ^{9}Be(^{238}U,X),E=1 GeV/nucleon. The ^{238}U beam was produced by the SIS synchrotron at GSI facility. Target=^{9}Be, 2500 mg/cm^2 thick. The fragment residues were analyzed with the high resolving power magnetic spectrometer Fragment separator (FRS). The identification of nuclei was made on the basis of magnetic rigidity, velocity, time-of-flight, energy loss and atomic number of the fragments using two plastic scintillators and two multisampling ionization chambers. The FRS magnet was tuned to center on ^{210}Au, ^{216}Pb, ^{219}Pb, ^{227}At and ^{229}At nuclei, along the central trajectory of the FRS. Unambiguous identification of nuclides required the separation of different charge states of the nuclei passing through the FRS. At 1 GeV/nucleon incident energy of ^{238}U, the fraction of fully stripped ^{226}Po nuclei was about 89%. Through the measurement of difference in magnetic rigidity in the two sections of the FRS and the difference in energy loss in the two ionization chambers, the charge state of the transmitted nuclei was determined, especially, that of the singly charged (hydrogen-like) nuclei which preserved their charge in the current experimental setup. Measured production cross sections. Criterion stated in 2010Al24 for acceptance of identification of a new nuclide were: 1. number of events should be compatible with the corresponding mass and atomic number located in the expected range of positions at both the image planes of the FRS spectrometer; 2. number of events should be compatible with >95% probability, that at least one of the counts did not correspond to a charge-state contaminant. Comparisons of measured σ was made with the model predictions using the COFRA and EPAX computer codes.

2017Ca12, 2016Ca25 (also 2014Ca23): ^{218}Pb produced in fragmentation of 1 GeV/nucleon ^{238}U beam from SIS-18 synchrotron at GSI on a ^{9}Be target of 1.6 g/cm^2 thickness. Reaction products were separated and identified by the GSI Fragment Separator (FRS) using Bρ-ΔE-Bρ technique. The FRS tracking detectors were four time-projection chambers (TPCs), two ionization chambers, and thin plastic scintillators for TOF measurement. Mass-over-charge (A/Q) ratios were measured for ions analyzed on an event-by-event basis. Finally selected ions of interest were implanted into a stack of double-sided silicon strip detectors SIMBA, which also detected the β-decay events. Comparison with theoretical calculations was made using FRDM+QRPA, DF3+cQRPA KTUY and RHB+RQRPA models. (cQRPA=continuum quasi-random-phase approximation; FRDM=finite−range droplet model; DF3=density functional theory; RHB=relativistic Hartree-Bogoliubov; RQRPA=relativistic QRPA; KTUV=Koura−Tachibana−Uno−Yamada model).

Theory references: consult NSR database (www.nndc.bnl.gov/nsr/) for 20 primary references for nuclear structure, seven for half-lives of different modes of radioactive decays, and four for nuclear reactions.

^{218}Pb Levels

E(level)	J$^\pi$	T$_{1/2}$	Comments
0	0$^+$	15 s *7*	%β^-=100 Only the β^- decay mode is expected, and has been observed by 2017Ca12. In A/Z plot (Fig. 1 in 2010Al24), ≈80 events are assigned to ^{218}Pb. T$_{1/2}$: measured by 2017Ca12 and 2016Ca25 from (ion)β correlated decay curve and analyzed by maximum-likelihood method. Production cross section σ=1.43 nb *14*(stat) *29*(syst) measured by 2010Al24. values are given in Fig. 2 plot of σ versus mass number for Pb isotopes (also from e-mail reply of Oct 29, 2010 to B. Singh from H. Alvarez-Pol).

Adopted Levels

Q(β^-)=4859 *27*; S(n)=3590 *30*; S(p)=6310 *SY*; Q(α)=4330 *SY* 2017Wa10
Estimated uncertainties (2017Wa10): 300 for S(p), 200 for Q(α).
S(2n)=8801 *29*, S(2p)=16080 *300* (syst) (2017Wa10).

1998Pf02: ^{218}Bi nuclide produced and identified in ^{9}Be(^{238}U,X) reaction at E(^{238}U)=1 GeV/nucleon.

2004De16, 2004Fr14 (also 2004DeZV thesis): ^{218}Bi nuclide produced in spallation reaction with a 1.4-GeV proton beam on a uranium carbide target at ISOLDE facility.

2010Al24 (also 2009Al32): ^{218}Bi nuclide identified in ^{9}Be(^{238}U,X),E=1 GeV/nucleon, beam produced by the SIS synchrotron at GSI facility. The fragment residues were analyzed with the high resolving power magnetic spectrometer Fragment separator (FRS).

2012Be28: ^{218}Bi was produced in projectile fragmentation of ^{238}U at 1 GeV/nucleon beam provided by the UNILAC-SIS accelerator at GSI with an intensity of 1.5×10^{9} ions/spill (a repetition of 3 s and an extraction time of 1 s), bombarding a ^{9}Be target. Reaction products were separated and identified in the magnetic spectrometer Fragment Separator (FRS), and implanted in a composite DSSSD detector system comprising three layers, each with three DSSSD pads with 16x16 pixels. The DSSSD detectors were surrounded by the RISING γ-ray spectrometer array of 105 Ge crystals arranged in 15 clusters. Measured γ, $\beta\gamma$(t) in coincidence with implanted recoils. A total of 6678 implanted ^{218}Bi ions were detected.

2014Mo02, 2014Mo15: ^{218}Bi was produced in projectile fragmentation of 1 GeV/nucleon ^{238}U beam from UNILAC-SIS accelerator at GSI, bombarding a ^{9}Be target. The reaction products were separated and identified in the magnetic spectrometer Fragment Separator (FRS), based on Bρ-ΔE-Bρ scheme.

2017Ca12, 2016Ca25 (also 2014Ca23): ^{218}Bi produced in fragmentation of 1 GeV/nucleon ^{238}U beam from SIS-18 synchrotron at GSI on a ^{9}Be target of 1.6 g/cm^{2} thickness. Reaction products were separated and identified by GSI Fragment Separator (FRS) using Bρ-ΔE-Bρ technique. The FRS tracking detectors were four time-projection chambers (TPCs), two ionization chambers, and thin plastic scintillators for tof measurement. Mass-over-charge (A/Q) ratios were measured for ions analyzed on an event-by-event basis. Finally selected ions of interest were implanted into a stack of double-sided silicon strip detectors SIMBA, which also detected β-decay events. Comparison with theoretical calculations using FRDM+QRPA, DF3+cQRPA KTUY and RHB+RQRPA models. (cQRPA=continuum quasi-random-phase approximation; FRDM=finite−range droplet model; DF3=density functional theory; RHB=relativistic Hartree-Bogoliubov; RQRPA=relativistic QRPA; KTUV=Koura−Tachibana−Uno−Yamada model).

Mass measurement: 2012Ch19 (also 2008ChZI thesis).

Theory references: consult NSR database (www.nndc.bnl.gov/nsr/) for six primary references for calculations of half-lives of radioactive decays.

^{218}Bi Levels

E(level)	J^π	$T_{1/2}$	Comments
0	(6^-,7^-,8^-)	33 s *1*	%β^-=100 $T_{1/2}$: from time scaling measurement of γ rays (2004De16). Others: 36 s *14* (2012Be28, $\beta\gamma$-coin decay curve by summing time spectra for 262-, 385- and 425-keV transitions); 38.5 s *216* (2017Ca12, rounded to 38 s *22* in 2016Ca25; (ion)β correlated decay curve and analyzed by maximum-likelihood method). E(level): the 33-s activity is assumed as the ground state, probably with J≥6 since it possibly feeds (4^+), (6^+) and (8^+) states in ^{218}Po. 2004De16 state that there is no evidence for a low-spin isomeric state. J^π: from the observed direct β-feedings to the (6^+) and (8^+) levels of ^{218}Po, and expected coupling of $\pi h_{9/2}$ orbital with $\nu g_{9/2}$ and/or other positive-parity neutron orbitals . Shell-model calculations by 2004De16, with the consideration of $\pi h_{9/2}$, $\nu g_{9/2}$, and $\nu i_{11/2}$ multiplets, predicted 8^- as the ground state, with the 7^- and 6^- states lying only ≈40 keV above the g.s. For Z=83 isotopes, g.s. Jπ values are $9/2^-$ or ($9/2^-$) for odd-A from A=209 to 217, suggesting $h_{9/2}$ proton orbital in the g.s. configuration for ^{218}Bi. For N=135 isotones, g.s. Jπ=($9/2^+$) for ^{219}Po, $7/2^+$ for ^{221}Rn, $3/2^+$ for ^{223}Ra and ($3/2^+$) for ^{225}Th do not suggest a single neutron orbital for g.s. of ^{218}Bi.

Adopted Levels, Gammas

Q(β^-)=259 *12*; S(n)=5598 *7*; S(p)=7662 *18*; Q(α)=6114.75 *9* 2017Wa10
S(2n)=9568.2 *20*; S(2p)=13700 *200* (syst) (2017Wa10).
Nuclide assignment: ^{218}Po activity of 3 min first identified from decay of Ra by E. Rutherford and H.T. Barnes, Phil. Mag. 7, 202 (1904). See 2013Fr04 for a brief description of discovery of this isotope.
Theory references: consult NSR database (www.nndc.bnl.gov/nsr/) for 56 primary references for calculations of half-lives of radioactive decay modes, and 10 for nuclear structure.

^{218}Po Levels

Cross Reference (XREF) Flags

A ^{218}Bi β^- decay (33 s)
B ^{222}Rn α decay (3.8222 d)

E(level)†	Jπ‡	$T_{1/2}$	XREF	Comments
0.0	0^+	3.097 min *12*	AB	%α=99.980 *2*; %β^-=0.020 *2* Evaluated rms charge radius=5.6558 fm *173* (2013An02). Evaluated charge radius relative to ^{208}Po: $\delta\langle r^2\rangle(^{218}Po,^{208}Po)$=+1.092 fm^2 *15* (2013An02). %β^-: unweighted average from 1958Wa16 (%β^-=0.0185) and 1952Hi60 (%β^-=0.022 *3*). Earlier measurements: 1943Ka04, 1944Ka01, 1949Wa05. %β^- was deduced from intensity of ^{218}At α group observed to grow into fresh ^{218}Po sample. $T_{1/2}$: from α decay; weighted average of 1982Va09 (3.11 min *2*) and 1986Po17 (3.093 min *12*). Other: 3.05 min (1931Cu01 evaluation). RMS nuclear charge radius relative to that of ^{210}Po: $\delta\langle r^2\rangle(^{218}Po,^{210}Po)$=+0.958 fm^2 *10*(stat) *7*(syst) (2011Co01,2012Co24). RMS nuclear charge radius relative to that of ^{210}Po: $\delta\langle r^2\rangle(^{218}Po,^{210}Po)$=+0.948 fm^2 *10*(stat) *7*(syst) (2015Fi07).
509.70 *10*	2^+		AB	Jπ: γ to g.s.; α decay from 0^+ ^{222}Rn; $\alpha\gamma(\theta)$ measurement of 1989Po03 rules out J=1,3.
676? *4*			B	E(level): from Eα of a weak α branch in ^{222}Rn α decay.
935.20 *15*	(4^+)		A	
1320.90 *18*	(6^+)		A	
1583.90 *20*	(8^+)		A	
1757.9 *3*			A	
1858.70 *20*			A	
1871.0 *3*			A	
2002.2 *6*			A	
2047.5 *6*			A	
2286.8 *4*			A	

† From a least-squares fit to Eγ data, by evaluators except where noted.
‡ From systematics of even-even nuclides in this mass region, unless otherwise stated.

$\gamma(^{218}Po)$

E_i(level)	J_i^π	E_γ†	I_γ†	E_f	J_f^π	Mult.	α‡
509.70	2^+	509.7 *1*	100	0.0	0^+	[E2]	0.0307
935.20	(4^+)	425.5 *1*	100	509.70	2^+	[E2]	0.0478
1320.90	(6^+)	385.7 *1*	100	935.20	(4^+)	[E2]	0.0619

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Adopted Levels, Gammas (continued)

$\gamma(^{218}Po)$ (continued)

E_i(level)	J_i^π	E_γ†	I_γ†	E_f	J_f^π	Mult.	α‡
1583.90	(8$^+$)	263.0 *1*	100	1320.90	(6$^+$)	[E2]	0.189
1757.9		174.5 *9*	5.0 *25*	1583.90	(8$^+$)		
		437.0 *2*	100 *50*	1320.90	(6$^+$)		
1858.70		537.8 *1*	100	1320.90	(6$^+$)		
1871.0		287.1 *2*	100	1583.90	(8$^+$)		
2002.2		418.3 *5*	100	1583.90	(8$^+$)		
2047.5		176.6 *9*	1.6 *16*	1871.0			
		463.5 *6*	100 *33*	1583.90	(8$^+$)		
2286.8		702.9 *3*	100	1583.90	(8$^+$)		

† From ^{218}Bi β^- decay.

‡ Total theoretical internal conversion coefficients, calculated using the BrIcc code (2008Ki07) with Frozen orbital approximation based on γ-ray energies, assigned multipolarities, and mixing ratios, unless otherwise specified.

^{218}Bi β^- decay (33 s) 2004De16,2014Mo02

Parent: ^{218}Bi: E=0; J$^\pi$=(6$^-$,7$^-$,8$^-$); T$_{1/2}$=33 s *1*; Q(β^-)=4859 *27*; %β^- decay=100.0
^{218}Bi-E,J$^\pi$,T$_{1/2}$: From ^{218}Bi Adopted Levels.
^{218}Bi-Q(β^-): From 2017Wa10.
2004De16 (also 2004Fr14): ^{218}Bi produced in spallation reaction with a 1.4-GeV proton beam on a uranium carbide target at ISOLDE facility. Measured Eγ, Iγ, γγ, βγγ coin, T$_{1/2}$ of ^{218}Bi nuclide.
2014Mo02: ^{218}Bi produced at the accelerator system of GSI facility. A ^{238}U beam at 1 GeV/nucleon on a Be target produced fragmentation species which were separated using the FRS spectrometer via Bρ-ΔE-Bρ method. Selected nuclei were identified via time-of-flight detectors and ionizing chambers (MUSIC), and implanted in a DSSSD detector. Half-lives were determined via spatial and time correlations between implants and β decays. The HPGe based RISING γ-ray spectrometer surrounding the DSSSD stack allowed the correlation of decays with γγ coincidences.
Other: 1998Pf02: ^{218}Bi nuclide identified in ^{9}Be(^{238}U,X) E=1 GeV/nucleon.

^{218}Po Levels

E(level)†	J$^\pi$‡	T$_{1/2}$‡	E(level)†	J$^\pi$‡	E(level)†
0.0	0$^+$	3.097 min *12*	1583.90 *20*	(8$^+$)	2002.2 *6*
509.70 *10*	2$^+$		1757.9 *3*		2047.5 *6*
935.20 *15*	(4$^+$)		1858.70 *20*		2286.8 *4*
1320.90 *18*	(6$^+$)		1871.0 *3*		

† From least-squares fit to Eγ data, by evaluators.
‡ From the Adopted Levels.

β^- radiations

E(decay)	E(level)	Iβ$^-$†‡	Log *ft*†
(2.57×10^3 *3*)	2286.8	7 *2*	6.3 *1*
(2.81×10^3 *3*)	2047.5	5 *2*	6.6 *2*
(2.86×10^3 *3*)	2002.2	5 *2*	6.7 *2*
(2.99×10^3 *3*)	1871.0	<0.2	>8.1
(3.00×10^3 *3*)	1858.70	9 *2*	6.5 *1*
(3.10×10^3 *3*)	1757.9	4 *2*	6.9 *2*
(3.28×10^3 *3*)	1583.90	28 *7*	6.2 *1*
(3.54×10^3# *3*)	1320.90	26 *13*	6.3 *2*
(3.92×10^3# *3*)	935.20	<19	>6.6

† Deduced by the evaluators from γ-ray intensity balance at each level. Values should be considered as upper limits since there is a large gap between Q value and the highest observed level at 2287. Also the uncertainties on γ-ray intensities are quite large.
‡ Absolute intensity per 100 decays.
# Existence of this branch is questionable.

γ(^{218}Po)

Iγ normalization: I(γ+ce)(509.7γ)=100, assuming no β^- feeding to g.s.

Eγ†	Iγ†§	E$_i$(level)	E$_f$	J$^\pi_f$	Mult.	α&	Comments
174.5 *9*	0.2 *1*	1757.9	1583.90	(8$^+$)	[D,E2]	1.2 *11*	Iγ: from Figure 2 of 2004De16, <2.2 in Table I of 2004De16.
176.6 *9*	0.1 *1*	2047.5	1871.0		[D,E2]	1.2 *11*	Iγ: from Figure 2 of 2004De16, <1.3 in Table I of 2004De16.
263.0‡ *1*	49 *5*	1583.90	1320.90	(6$^+$)	[E2]	0.189	Iγ: weighted average of 59 *16* (2004De16) and 48 *5* (2014Mo02).

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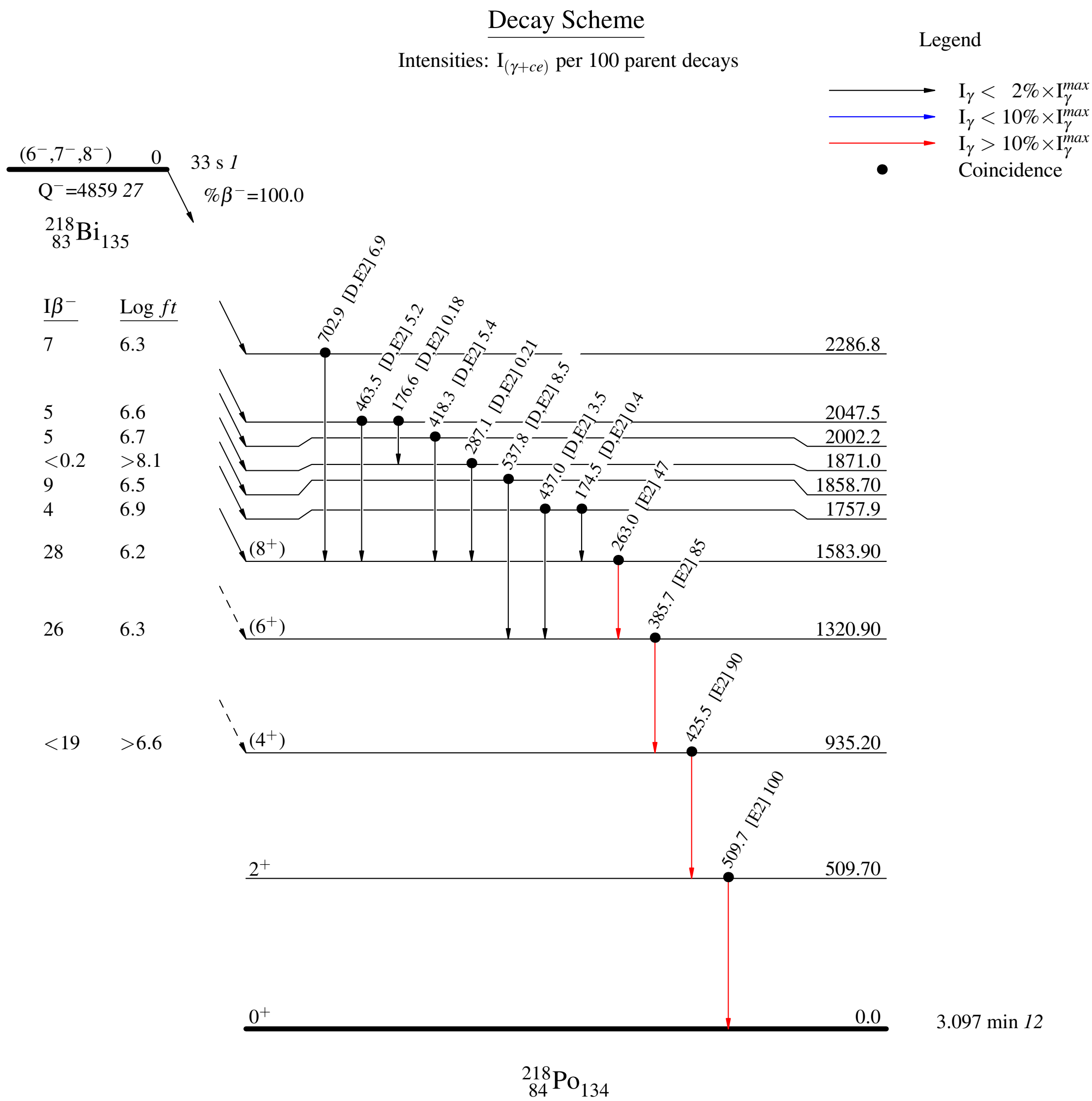
^{218}Bi β^- decay (33 s) 2004De16,2014Mo02 (continued)

$\gamma(^{218}Po)$ (continued)

E_γ †	I_γ †§	E_i(level)	J_i^π	E_f	J_f^π	Mult.	α &	Comments
287.1 *2*	0.2 *1*	1871.0		1583.90	(8$^+$)	[D,E2]	0.32 *28*	I_γ: from Figure 2 of 2004De16, <2.7 in Table I of 2004De16.
385.7‡ *1*	100 *9*	1320.90	(6$^+$)	935.20	(4$^+$)	[E2]	0.0619	I_γ: from 2014Mo02, as values is reported with no uncertainty in 2004De16.
418.3 *5*	6 *2*	2002.2		1583.90	(8$^+$)	[D,E2]	0.12 *10*	
425.5‡ *1*	107 *10*	935.20	(4$^+$)	509.70	2$^+$	[E2]	0.0478	I_γ: weighted average of 95 *27* (2004De16) and 109 *10* (2014Mo02).
437.0 *2*	4 *2*	1757.9		1320.90	(6$^+$)	[D,E2]	0.10 *9*	
463.5 *6*	6 *2*	2047.5		1583.90	(8$^+$)	[D,E2]	0.09 *8*	
509.7 *1*	121 *11*	509.70	2$^+$	0.0	0$^+$	[E2]	0.0307	I_γ: weighted average of 134 *42* (2004De16) and 120 *11* (2014Mo02).
537.8 *1*	10 *2*	1858.70		1320.90	(6$^+$)	[D,E2]	0.06 *5*	I_γ: weighted average of 12 *3* (2004De16) and 9 *2* (2014Mo02).
702.9 *3*	8.4 *20*	2286.8		1583.90	(8$^+$)	[D,E2]	0.030 *25*	I_γ: weighted average of 7 *3* (2004De16) and 9 *2* (2014Mo02).

† From 2004De16, except where noted.
‡ Ordering of the cascade is based on systematics in this mass region.
§ For absolute intensity per 100 decays, multiply by 0.80 *7*.
& Total theoretical internal conversion coefficients, calculated using the BrIcc code (2008Ki07) with Frozen orbital approximation based on γ-ray energies, assigned multipolarities, and mixing ratios, unless otherwise specified.

^{218}Bi β^- decay (33 s) 2004De16,2014Mo02



^{222}Rn α decay (3.8222 d) 1958Wa16,1956Ma28,1971Gr17

Parent: ^{222}Rn: E=0.0; $J^\pi=0^+$; $T_{1/2}$=3.8222 d *9*; Q(α)=5590.4 *3*; %α decay=100.0

^{222}Rn-$T_{1/2}$: weighted average of 3.82146 d *85* (2015Be07, from decay curve for integral γ-ray spectrum from 6 keV onwards, weighted average of four measurements: 3.82157 d *32* for 1301 h, 3.82134 d *30* for 1462 h, 3.82169 d *32* for 1185 h, and 3.82124 d *35* for 1357 h; statistical uncertainty of 0.00016 d and systematic uncertainty of 0.00004 d in 2015Be07 combined in quadrature, and total uncertainty increased to 0.00085, to have a maximum relative weight of 50%); 3.8195 d *30* (2004Sc04, ionization chamber, reanalysis of 2004Sc04 data by 2018Po01 gave 3.825 d *5*); 3.8224 d *18* (1995Co34, 4π $\alpha\beta$ liquid scintillation counter, average of six measurements); 3.82351 d *170* (1972Bu33, decay curve for integral γ-ray spectrum measured over 40 half-lives, average of two measurements, quoted uncertainty of 0.00034 increased to 0.00170 as in 1990Ho28 evaluation); 3.83 d *3* (1958Sh69, calorimetry); 3.82290 d *170* (1956Ma64, ionization chamber, average of three measurements, quoted uncertainty of 0.00027 increased to 0.00170 as in 1990Ho28); 3.825 d *5* (1956Ro31, calorimetry, quoted uncertainty of 0.004 increased to 0.005 as in 1990Ho28); 3.825 d *6* (1955To07,1951To25, ionization chamber, average of two measurements, quoted uncertainty of 0.005 increased to 0.006 as in 1990Ho28); 3.823 d *3* (1924Cu01, ionization chamber, average of four measurements, quoted uncertainty of 0.002 increased to 0.003 as in 1990Ho28); 3.825 d *4* (1923Bo01, ionization chamber, average of four measurements). Other nominal recent value=3.81 d *12* (2018Ap01). Measurements prior to 1923, cited from compilation in 1995Co34 and 1995Co35: 3.811 d (1921Bo01); 3.847 d (1913RuZZ); 3.85 d (1910Cu02); 3.747 d (1907Ru04); 3.863 d (1905Sa01); 3.896 d (1904Bu01); 3.71 d (1903Ru05); 3.987 d (1902Cu01).

^{222}Rn-Q(α): From 2017Wa10.

^{222}Rn-%α decay: %α=100 since %ε<1×10^{-4}, estimated from log *ft* value for possible ε transition to ^{222}Fr.

1958Wa16: measured Eα, Iα.

1956Ma28: measured Eγ.

1971Gr17: measured Eα.

Others:

2018St04, 2018Po01, 2015Be07: measured $T_{1/2}$ of ^{222}Rn decay, and emitted α and γ radiation to investigate annual, solar and diurnal oscillations of half-life, but no evidence found.

1998Mo14: emission probabilities of γ rays from daughters of ^{222}Rn.

1989Po03: measured $\alpha\gamma(\theta)$.

1987Er06: measured α(x ray) coin, deduced K-shell ionization probability.

1996Wi27, 1963Ba62, 1953Ba29, 1936Br05: measured Eα.

1968Bi08: measured $\alpha\alpha(\theta)$.

$T_{1/2}$(^{222}Rn isotope): 2015Be07, 2004Sc04, 1995Co34, 1972Bu33, 1958Sh69, 1956Ro31, 1956Ma64, 1951To25, 1924Cu01, 1923Bo01.

From (α)(K x-ray) coin, K-shell ionization probability following α decay is deduced to be 3.75×10^{-6} *25* (1987Er06).

^{218}Po Levels

E(level)‡	J^π†	$T_{1/2}$†	Comments
0.0	0^+	3.097 min *12*	
513 *1*	2^+		J^π: not 1 and 3 from $\alpha\gamma(\theta)$ (1989Po03).
676? *4*			

† From the Adopted Levels.

‡ Derived from E_α and Q_α.

^{222}Rn α decay (3.8222 d) 1958Wa16,1956Ma28,1971Gr17 (continued)

α radiations

Eα†	E(level)	Iα‡@	HF#	Comments
4826 *4*	676?	≈0.0005	≈29	
4986 *1*	513	0.078 *1*	1.87 *3*	(4986α)(510γ)(θ): A_2=+0.4 *4*, A_4=−1.4 *8* (1989Po03).
5489.48 *30*	0.0	99.92 *1*	1.00	Eα: from 1971Gr17. The original energy has been decreased by 0.18 keV, as recommended by 1991Ry01. Other measurements: 1936Br05, 1953Ba29, 1963Ba62, 1964Wa19, 1996Wi27.

† From 1958Wa16, except where indicated.
‡ From 1958Wa16.
# $r_0(^{218}Po)$=1.54863 *17* from HF(5489.48α)=1.0.
@ Absolute intensity per 100 decays.

$\gamma(^{218}Po)$

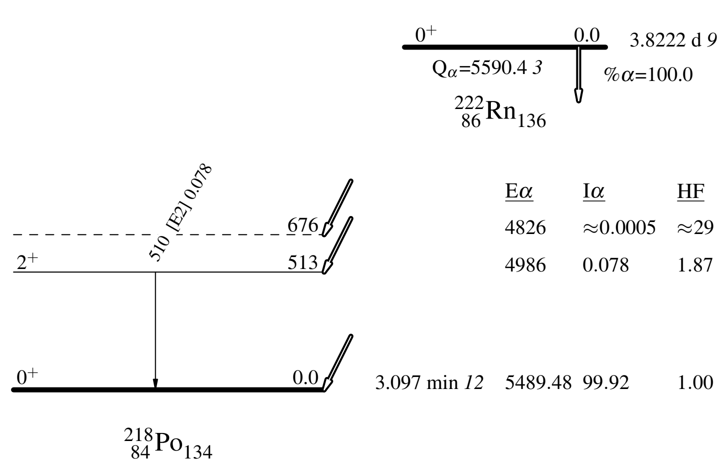
Eγ	Iγ†	E_i(level)	J_i^π	E_f	J_f^π	Mult.	α‡	$I_{(\gamma+ce)}$†	Comments
510 *2*	0.076 *1*	513	2+	0.0	0+	[E2]	0.0306 *6*	0.078 *1*	Eγ: from 1956Ma28. Iγ: from I(γ+ce) and α(theory). Measured value is Iγ≈0.07 (1956Ma28). $I_{(\gamma+ce)}$: from Iα.

† Absolute intensity per 100 decays.
‡ Total theoretical internal conversion coefficients, calculated using the BrIcc code (2008Ki07) with Frozen orbital approximation based on γ-ray energies, assigned multipolarities, and mixing ratios, unless otherwise specified.

^{222}Rn α decay (3.8222 d) 1958Wa16,1956Ma28,1971Gr17

Decay Scheme

Intensities: $I_{(\gamma+ce)}$ per 100 parent decays



Adopted Levels

Q(β^-)=2881 *12*; S(n)=4368 *13*; S(p)=5074 *13*; Q(α)=6874 *3* 2017Wa10
S(2n)=10301 *12*, S(2p)=12354 *16* (2017Wa10).
2019Ba22: hyperfine-structure measurements for the 795-nm atomic transitions in ^{218}At at CERN-ISOLDE, using the in-source resonance-ionization laser spectroscopy technique. The ^{218}At source prepared in U(p,X),E=1.4 GeV reaction using UC_x target. Deduced change in rms charge radius, isotope shift, magnetic moment and quadrupole moment.
No information is available from ^{218}Po β^- decay to ^{218}At.
^{218}At α decay experimental study: 1990Mo08.
Theory references: consult NSR database (www.nndc.bnl.gov/nsr/) for 11 primary references for calculations of half-lives of radioactive decays, and one for nuclear structure.

^{218}At Levels

E(level)	J$^\pi$	$T_{1/2}$	Comments
0	(3^-,2^-)	1.28 s *6*	%α=99.95 *5*; %β^-=0.05 *5* Static magnetic dipole moment μ=+1.25 *12*(stat) *3*(syst) for J=3, +1.195 *84*(stat) *29*(syst) for J=2 (2019Ba22). Static electric quadrupole moment Q=+0.55 *33*(stat) *27*(syst) for J=3, +0.63 *33*(stat) *32*(syst) for J=2 (2019Ba22). Change in rms charge radius $<r^2>$(^{218}At,^{205}At)=+1.349 *11*(stat) *70*(syst) for J=3, +1.369 *11*(stat) *71*(syst) for J=2 (2019Ba22). %α=99.9 and %β^-=0.1 were deduced by 1949Wa05 from α intensities of ^{218}At and ^{218}Rn. These results are consistent with non-observation of α decay from ^{218}Rn (β^- daughter of ^{218}At decay) in the study of ^{218}At α decay by 2019Cu02. Theoretical partial $T_{1/2}$>100 s for ^{218}At β decay and (2019Mo01) gives %β^-<1.3. $T_{1/2}$: from α decay curve. Weighted average of 1.27 s *6* (2019Cu02), 1.5 s *3* (1989Bu09), 1.3 s *1* (1958Wa16,1949Wa05). Other: ≈2 s (1952Hi60). J$^\pi$: (3^-) proposed by 2019Cu02 from favored α branch to 63-keV level in ^{214}Bi with Jπ=(3^-) (from 1991Be06), but authors did not rule out (2^-). See also authors′ companion paper 2019Ba22, where an expected configuration=$\pi 1h_{9/2} \otimes \nu 2g_{9/2}$ is suggested, with admixture from other configuration(s) from a comparison of measured magnetic dipole moment in 2019Ba22, with that predicted from additivity rule for neighboring odd-A isotopes. From Ω(proton)=3/2 and Ω(neutron)=1/2 in 2019Mo01, J=1,2. From systematics, 2017Au03 assigned 1^-.

^{218}Po β^- decay (3.097 min) 1958Wa16,1952Hi60

Parent: ^{218}Po: E=0; J$^{\pi}$=0^{+}; $T_{1/2}$=3.097 min *12*; Q(β^-)=259 *12*; %β^- decay=0.0200 *20*
^{218}Po-$T_{1/2}$: From ^{218}Po Adopted Levels.
^{218}Po-Q(β^-): From 2017Wa10.
^{218}Po-%β^- decay: %β^-=0.020 *2* for ^{218}Po decay from ^{218}Po Adopted Levels, where data were taken from 1958Wa16 and 1952Hi60.
^{218}Po decays mainly by α decay. Except for β^- branching of 0.020%, no other information is available for ^{218}Po β^- decay to ^{218}At.

Adopted Levels, Gammas

Q(β^-)=−1842 *5*; S(n)=6512 *4*; S(p)=6466 *5*; Q(α)=7262.5 *19* 2017Wa10
S(2n)=11178 *6*, S(2p)=11143.0 *27* (2017Wa10).
Isotopic assignment: 1948St42.
2019An10: measured mass excess=5089 keV *54* as compared to 5217.2 keV *23* in 2017Wa10. Note that negative sign in 2019An10 is a misprint.
Theory references: consult NSR database (www.nndc.bnl.gov/nsr/) for 42 primary references for calculations of half-lives of radioactive decay modes, and 20 for nuclear structure.

^{218}Rn Levels

Cross Reference (XREF) Flags

A ^{222}Ra α decay (33.6 s)
B ^{232}Th(^{136}Xe,Xγ)

E(level)†	J$^\pi$‡	T$_{1/2}$	XREF	Comments
0.0#	0+	33.75 ms *15*	AB	%α=100 Evaluated rms charge radius=5.6540 fm *187* (2013An02). Evaluated charge radius relative to ^{212}Rn: $\delta\langle r^2\rangle$(^{218}Rn,^{212}Rn)=+0.7000 fm^2 *3* (2013An02). T$_{1/2}$: From 2012Su11, delayed $\alpha\alpha$-coin method. Others: 39 ms *2* (1971Er02), 35 ms *1* (1963Di05), 30 ms *3* (1961Ru06), 19 ms (1948St42).
324.320# *18*	2+	<80 ps	AB	J$^\pi$: E2 324γ to 0+. T$_{1/2}$: from (α)(324γ)(t) in ^{222}Ra α decay (1960Be25).
653.18# *18*	(4+)		AB	J$^\pi$: 329γ to 2+, rotational band assignment in (^{136}Xe,Xγ).
796.911 *21*	(3−)		A	J$^\pi$: (E1) 473γ to 2+; γ to (4+).
840.172@ *18*	(3−)		AB	
1014.3# *3*	(6+)		B	
1026.1@ *4*	(5−)		B	
1327.9@ *4*	(7−)		B	
1392.9# *4*	(8+)		B	
1694.3@ *5*	(9−)		B	
1775.2# *4*	(10+)		B	
2070.9@ *7*	(11−)		B	
2168.9# *7*	(12+)		B	
2457.9@ *9*	(13−)		B	
2576.6# *8*	(14+)		B	
2853.0?@ *10*	(15−)		B	
3002.0# *10*	(16+)		B	
3265.2?@ *11*	(17−)		B	
3437.5# *11*	(18+)		B	
3683.2?@ *13*	(19−)		B	
3859.4# *12*	(20+)		B	
4287.0# *13*	(22+)		B	
4725.0# *14*	(24+)		B	
5167.8?# *15*	(26+)		B	

† From a least-squares fit to Eγ, by evaluators.

Continued on next page (footnotes at end of table)

Adopted Levels, Gammas (continued)

^{218}Rn Levels (continued)

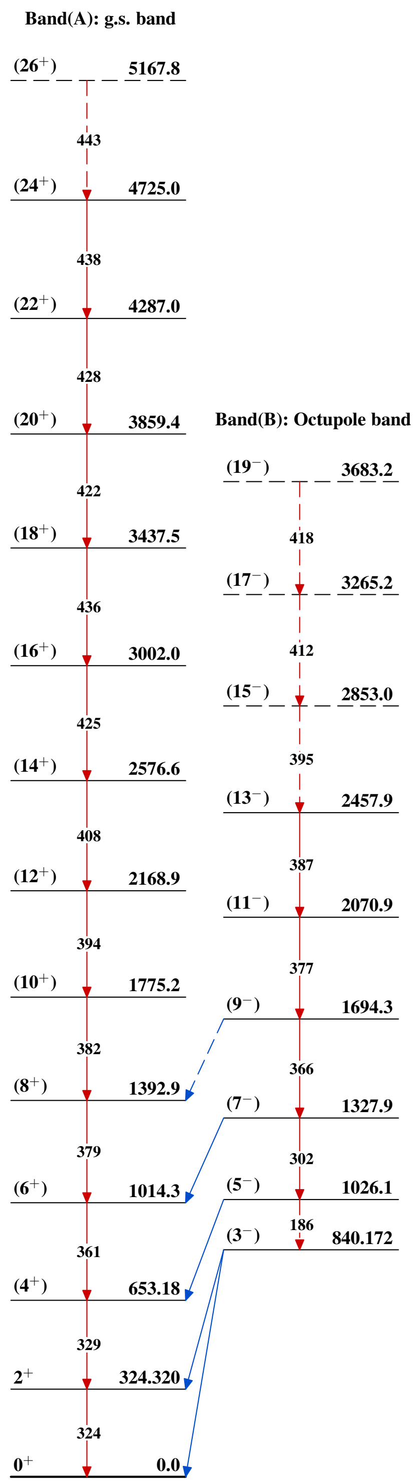
‡ From probable band assignments (g.s. band and an octupole band) for levels above the first 2^+ state.
# Band(A): g.s. band.
@ Band(B): Octupole band. For 7^- member, D_0/Q_0=0.000097 fm^{-1} *8*, from the γ-ray branching ratio and rotational model, where D_0 and Q_0 are intrinsic electric dipole moment and quadrupole moment, respectively.

$\gamma(^{218}Rn)$

E_i(level)	J_i^π	E_γ†	I_γ†	E_f	J_f^π	Mult.	α&	Comments
324.320	2^+	324.31‡ *2*	100	0.0	0^+	E2	0.1097	B(E2)(W.u.)>23 Mult.: from ce data in ^{222}Ra α decay.
653.18	(4^+)	328.9‡ *2*	100	324.320	2^+	[E2]	0.1053	
796.911	(3^-)	144.4§ *5*	2.8§ *5*	653.18	(4^+)	[E1]	0.190 *4*	
		472.59§ *1*	100§ *3*	324.320	2^+	(E1)		Mult.: from ce data in ^{222}Ra α decay.
840.172	(3^-)	515.83§ *3*	51§ *3*	324.320	2^+			
		840.18§ *2*	100§ *4*	0.0	0^+	[E3]		
1014.3	(6^+)	361.1 *2*	100	653.18	(4^+)			
1026.1	(5^-)	186.3@ *5*		840.172	(3^-)			
		372.7 *5*		653.18	(4^+)			
1327.9	(7^-)	302.0 *5*	100 *15*	1026.1	(5^-)			
		313.4 *5*	52 *12*	1014.3	(6^+)			
1392.9	(8^+)	378.6 *2*	100	1014.3	(6^+)			
1694.3	(9^-)	301.4@ *5*		1392.9	(8^+)			
		366.4 *5*		1327.9	(7^-)			
1775.2	(10^+)	382.3 *2*	100	1392.9	(8^+)			
2070.9	(11^-)	376.6 *5*	100	1694.3	(9^-)			
2168.9	(12^+)	393.7 *5*	100	1775.2	(10^+)			
2457.9	(13^-)	387.0 *5*	100	2070.9	(11^-)			
2576.6	(14^+)	407.7 *5*	100	2168.9	(12^+)			
2853.0?	(15^-)	395.1@ *5*		2457.9	(13^-)			
3002.0	(16^+)	425.4 *5*	100	2576.6	(14^+)			
3265.2?	(17^-)	412.2@ *5*		2853.0?	(15^-)			
3437.5	(18^+)	435.5 *5*	100	3002.0	(16^+)			
3683.2?	(19^-)	418.0@ *5*		3265.2?	(17^-)			
3859.4	(20^+)	421.9 *5*	100	3437.5	(18^+)			
4287.0	(22^+)	427.6 *5*	100	3859.4	(20^+)			
4725.0	(24^+)	438.0 *5*	100	4287.0	(22^+)			
5167.8?	(26^+)	442.8@ *5*		4725.0	(24^+)			

† From ^{232}Th(^{136}Xe,Xγ), except where noted.
‡ From ^{222}Rn α decay.
§ From ^{222}Rn α decay only.
& Total theoretical internal conversion coefficients, calculated using the BrIcc code (2008Ki07) with Frozen orbital approximation based on γ-ray energies, assigned multipolarities, and mixing ratios, unless otherwise specified.
@ Placement of transition in the level scheme is uncertain.

Adopted Levels, Gammas



$^{218}_{86}Rn_{132}$

^{222}Ra α decay (33.6 s) 1995Ko54,1976Ku08,1956As38

Parent: ^{222}Ra: E=0.0; $J^\pi=0^+$; $T_{1/2}$=33.6 s *4*; Q(α)=6678 *4*; %α decay=100.0

^{222}Ra-$T_{1/2}$: From 2012Po13 (from α activity measurement, decay curve and uncertainty details given). Others: 36.17 s *10* (1995Ko54, from γ activity measured for 32 samples, value is from authors′ text, also quoted as 36.0 s *1* in their abstract and 36.07 in Fig. 4, but decay curve and details of uncertainties not given); 43 s *4* (1982Bo04, from α activity in a complex α spectrum with contribution from many isotopes); 39 s *4* (1958To25); 37.5 s *20* and 36 s *2* (1956As38, from α activity); 38.0 s (1948St42).

^{222}Ra-Q(α): From 2017Wa10.

1995Ko54: measured $T_{1/2}$, Eγ, Iγ.

1991Ga28: $\alpha\alpha$ correlations from successive α decays.

1976Ku08: measured Eγ, Iγ.

1956As38: measured $T_{1/2}$, Eα, Iα, $\alpha\gamma$ coin.

$\alpha\gamma$: 1963Le17, 1969Pe17.

$\gamma\gamma$: 1960St20.

$\alpha\gamma(\theta)$: 1956Sm88.

$\alpha\gamma$(t): 1960Be25.

α(K)exp: 1974Va28, 1963Le17.

Analysis and syst of ^{222}Ra α decay data: 1987Po06.

^{218}Rn Levels

E(level)[†]	J^π[‡]	$T_{1/2}$[‡]	Comments
0.0	0^+	33.75 ms *15*	
324.320 *18*	2^+	<80 ps	$T_{1/2}$: from $\alpha\gamma$(t) (1960Be25). J^π: $\alpha\gamma(\theta)$ (1956Sm88) establishes 0-2-0 ($\alpha\gamma$) cascade.
653.12 *19*	(4^+)		
796.911 *21*	(3^-)		
840.172 *18*	(3^-)		

† From a least-squares fit to Eγ, by evaluators.

‡ From the Adopted Levels. 1995Ko54 assigned (2^+) to the 653 level and $(1^-,2^+)$ to the 797 and 840 levels based on g.s. transitions, but in the opinion of the evaluators, γ rays to g.s. are probably contributed by summing effects.

α radiations

Eα[†]	E(level)	Iα[@]	HF[#]	Comments
5733 *5*	840.172	0.0043[‡] *1*	4.37 *16*	Iα: other: 0.006% from $\alpha\gamma$ coin (1963Le17).
5775 *5*	796.911	0.0043[‡] *2*	7.1 *4*	Iα: other: 0.007% (1963Le17) from $\gamma\alpha$ coin.
5916 *5*	653.12	0.0043[‡] *2*	34.4 *19*	α was not observed due to presence of interfering transitions (1963Le17).
6239 *5*	324.320	3.05 *5*	1.44 *6*	Eα: other: energy was measured by 1961Ru06 relative to Eα(g.s.) and ΔQ(α)=326 *4* was given. Iα: from 1969Pe17. Others: 3.2% (1961Ru06), 4.1% *12* (1963Le17), 3.2% *2* (1975VaZD). Iα=3.09% *9* is deduced from level scheme.
6558 *5*	0.0	96.9 *1*	1.00	Eα: recommended by 1991Ry01 from measurement of 1956As38. The original energy has been increased by 4 keV because of change in calibration energy. Iα: weighted average of 96.95 *5* (1969Pe17) and 96.8 *2* (1975VaZD).

† Deduced by evaluators from level energies and Q(α)=6678 *4* (2017Wa10).

‡ Derived by evaluators using γ-ray intensity balance.

HF(6558α)=1.0 yields r_0(^{218}Rn)=1.5492 *22*.

@ Absolute intensity per 100 decays.

^{222}Ra α decay (33.6 s) 1995Ko54,1976Ku08,1956As38 (continued)

γ(^{218}Rn)

Iγ normalization: From absolute gamma-ray intensity (per 100 decays of the parent) of 324γ=2.77% *8* (1969Pe17).

A γ-ray with Eγ=653.14 keV *9* and Iγ(653γ)=0.00024 *4* was observed in 1995Ko54 and placed from the 653-keV level. 1995Ko54 note that random summing cannot be excluded from this observed transition. Adopted Jπ assignments give an M4 multipolarity for the 653γ transition and considering Iγ(516γ)=0.00142 *8* for the competing E1 depopulating transition, the transition strength for 653γ would be more than 10^6 W.u. larger than the E1 transition. Thus, the evaluators consider the 653γ to have resulted from summing and do not include it in this decay dataset.

E_γ†	I_γ‡§	E_i(level)	J^π_i	E_f	J^π_f	Mult.	α&	Comments
144.4 *5*	1.1×10^{-4} *2*	796.911	(3$^-$)	653.12	(4$^+$)	[E1]	0.190 *4*	E_γ: weighted average of 144.0 *5* (1976Ku08) and 144.8 *5* (1995Ko54). I_γ: from 1976Ku08. Other: <0.00025 *7* (1995Ko54).
324.31 *2*	2.77 *8*	324.320	2$^+$	0.0	0$^+$	E2	0.1097	E_γ: weighted average of 324.22 *5* (1976Ku08) and 324.31 *1* (1995Ko54). I_γ: from 1969Pe17. Mult.: from α(K)exp=0.059 (1974Va28).
328.9 *2*	0.0040 *1*	653.12	(4$^+$)	324.320	2$^+$	[E2]	0.1053	E_γ: other: 328.9 *2* (1976Ku08). I_γ: other: 0.0043 *5* (1976Ku08).
472.59 *1*	0.0039 *1*	796.911	(3$^-$)	324.320	2$^+$	[E1]	0.0124	E_γ: other: 472.5 *1* (1976Ku08). I_γ: other: 0.0040 *3* (1976Ku08). Mult.: possibly E1 from α(K)exp≈0.01 (α(ce) and αγ coin data of 1963Le17); but a definitive assignment could not be made from the available data (according to private communication from author of 1963Le17 to 1987El12).
515.83 *3*	0.00142 *8*	840.172	(3$^-$)	324.320	2$^+$	(E1)	0.0103	α(K)exp≈0.025 (1963Le17). E_γ: other: 515.6 *1* (1976Ku08). I_γ: other: 0.0015 *1* (1976Ku08). Mult.: from α(K)exp.
796.8@ *2*	0.00017 *5*	796.911	(3$^-$)	0.0	0$^+$	[E3]	0.0333	E_γ,I_γ: from 1995Ko54 only, probably contributed by coincidental summing of 472γ and 324γ.
840.18 *2*	0.0028 *1*	840.172	(3$^-$)	0.0	0$^+$	[E3]	0.0292	E_γ: other: 840.2 *2* (1976Ku08). I_γ: other: 0.0025 *2* (1976Ku08).

† From 1995Ko54, unless otherwise stated. Values from 1976Ku08 are consistent and provided in the comments. Others: 1974Va28, 1963Le17, 1956As38, 1956Sm88, 1960St20.

‡ From 1995Ko54, unless otherwise stated. Intensities are normalized to Iγ(324γ)=2.77% *8* (1969Pe17). Values from 1976Ku08 are consistent and provided in the comments. Others: 1963Le17, 1961Ru06, 1960St20, 1956As38.

§ Absolute intensity per 100 decays.

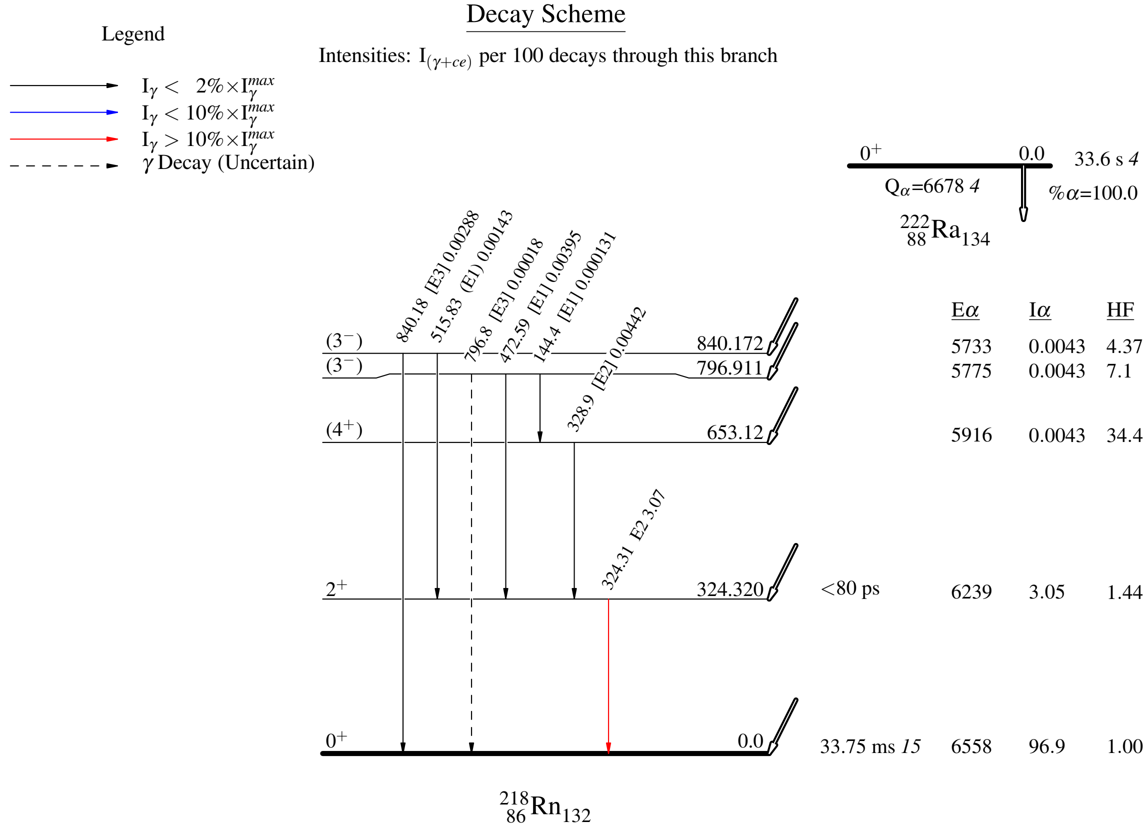
& Total theoretical internal conversion coefficients, calculated using the BrIcc code (2008Ki07) with Frozen orbital approximation based on γ-ray energies, assigned multipolarities, and mixing ratios, unless otherwise specified.

@ Placement of transition in the level scheme is uncertain.

^{222}Ra α decay (33.6 s) 1995Ko54,1976Ku08,1956As38

Decay Scheme

Intensities: $I_{(\gamma+ce)}$ per 100 decays through this branch



^{232}Th(^{136}Xe,Xγ) 1999Co02

1999Co02 (also 1998Bu17,1997Co08,1997Co14): E(^{136}Xe)=833 MeV. Measured Eγ, Iγ, γγγ using GAMMASPHERE array consisting of 73 HPGe detectors.

^{218}Rn Levels

E(level)†	Jπ‡	Comments
0.0#	0+	
324.5# *2*	2+	
653.5# *3*	(4+)	
796.7		No population or decay modes shown by 1999Co02.
840.0?@ *2*	(3−)	
1014.8# *7*	(6+)	
1026.2@ *5*	(5−)	
1328.2@ *7*	(7−)	D_0/Q_0=0.000097 fm^{-1} *8*, from the γ-ray branching ratio and rotational model, where D_0 and Q_0 are intrinsic electric dipole moment and quadrupole moment, respectively.
1393.4# *8*	(8+)	
1694.6@ *8*	(9−)	
1775.7# *8*	(10+)	
2071.2@ *10*	(11−)	
2169.4# *9*	(12+)	
2458.2@ *11*	(13−)	
2577.1# *11*	(14+)	
2853.5?@ *11*	(15−)	
3002.5# *12*	(16+)	
3265.7?@ *12*	(17−)	
3438.0# *13*	(18+)	
3683.7?@ *12*	(19−)	
3860.0# *14*	(20+)	
4287.5# *15*	(22+)	
4725.5# *16*	(24+)	
5168.5?# *16*	(26+)	

† From least-squares fit to Eγ data, by evaluators.
‡ As proposed by 1999Co02 based on observation of γ-ray cascades assigned to the g.s. band and an octupole band.
# Band(A): g.s. band.
@ Band(B): Octupole band.

γ(^{218}Rn)

Eγ†	Iγ	E_i(level)	J^π_i	E_f	J^π_f
186.3‡ *5*		1026.2	(5−)	840.0?	(3−)
301.4‡ *5*		1694.6	(9−)	1393.4	(8+)
302.0 *5*	33 *5*	1328.2	(7−)	1026.2	(5−)
313.4 *5*	17 *4*	1328.2	(7−)	1014.8	(6+)
324.5 *2*	100 *19*	324.5	2+	0.0	0+
329.0 *2*	96 *18*	653.5	(4+)	324.5	2+
361.1 *2*	83 *5*	1014.8	(6+)	653.5	(4+)
366.4 *5*	34 *5*	1694.6	(9−)	1328.2	(7−)
372.7 *5*	34 *5*	1026.2	(5−)	653.5	(4+)
376.6 *5*	38 *13*	2071.2	(11−)	1694.6	(9−)
378.6 *2*	68 *13*	1393.4	(8+)	1014.8	(6+)
382.3 *2*	49 *7*	1775.7	(10+)	1393.4	(8+)
387.0 *5*	24 *8*	2458.2	(13−)	2071.2	(11−)
393.7 *5*	39 *7*	2169.4	(12+)	1775.7	(10+)
395.1‡ *5*		2853.5?	(15−)	2458.2	(13−)
407.7 *5*	30 *3*	2577.1	(14+)	2169.4	(12+)
412.2‡ *5*		3265.7?	(17−)	2853.5?	(15−)
418.0‡ *5*		3683.7?	(19−)	3265.7?	(17−)

Continued on next page (footnotes at end of table)

^{232}Th(^{136}Xe,Xγ) 1999Co02 (continued)

γ(^{218}Rn) (continued)

E_γ †	I_γ	E_i(level)	J^π_i	E_f	J^π_f
421.9 *5*	10 *3*	3860.0	(20+)	3438.0	(18+)
425.4 *5*	21 *3*	3002.5	(16+)	2577.1	(14+)
427.6 *5*	7 *3*	4287.5	(22+)	3860.0	(20+)
435.5 *5*	13 *3*	3438.0	(18+)	3002.5	(16+)
438.0 *5*	5 *3*	4725.5	(24+)	4287.5	(22+)
442.8‡ *5*		5168.5?	(26+)	4725.5	(24+)

† Uncertainties assigned (by the evaluators) as 0.2 keV for transitions in the g.s. band up to 10+ and 0.5 keV for all other transitions based on a general comment by 1999Co02 that the uncertainties range from 0.2 keV for low-lying transitions in the g.s. band up to 0.5 keV for intraband transitions in the octupole band and higher-lying transitions.
‡ Placement of transition in the level scheme is uncertain.

Adopted Levels, Gammas

Q(β^-)=408 *12*; S(n)=5327 *8*; S(p)=3888 *6*; Q(α)=8014.0 *20* 2017Wa10
S(2n)=12054 *6*, S(2p)=9775 *6* (2017Wa10).
Isotopic assignment: 1951Me10 (from ^{226}Pa α-decay chain, also 1949Me54, as listed in 2013Fr09). Later studies: 1964Mc21, 1968Ha14, 1972Es03.
Theory references: consult NSR database (www.nndc.bnl.gov/nsr/) for 14 primary references for calculations of half-lives of radioactive decay modes, and three for nuclear structure.

^{218}Fr Levels

Shell-model calculations were carried out by the evaluators to compare the low-lying negative-parity structures up to 10$^-$ and excitation energy of 1 MeV using NuShellX@MSU code with jj67pn interaction, and ^{208}Pb core with 5 valence protons in 1h$_{9/2}$ and 2f$_{7/2}$ orbitals, and 5 valance neutrons in 1i$_{11/2}$ and 2g$_{9/2}$ orbitals.

Cross Reference (XREF) Flags

A	^{222}Ac α decay (4.9 s)
B	^{222}Ac α decay (64 s)
C	^{209}Bi(^{18}O,2αnγ)

E(level)[†]	Jπ[#]	$T_{1/2}$	XREF	Comments
0.0	1$^-$	1.1 ms +*5*−*4*	AB	%α=100 Only α decay has been observed by 1964Mc21 and 1982Ew01. Jπ: favored α decay to 1$^-$ ^{214}At g.s. Evaluators′ shell-model calculations also predict 1$^-$ g.s. $T_{1/2}$: from α-decay curve. Weighted average of 0.7 ms *6* (1964Mc21) and 1.3 ms +*5*−*4* (1982Ew01).
0+x[&]	(9$^-$)		C	2014Bu06 suggested that this level may be the same as the 86-keV level with Jπ=(8$^-$) from 1999Sh03 due to similar configuration as reported by 2000De36.
46[‡] *11*			AB	
86 *8*	(8$^-$,9$^-$)	21.9 ms *5*		%α≈100 μ=+2.68 *4* (2014Bu06) μ: from hyperfine structure using collinear resonance ionization spectroscopy at ISOLDE-CERN. The value corresponds to Jπ=8$^-$. For 9$^-$, 2014Bu06 give μ=+2.70 *4*. Only the α-decay mode has been observed. The isomeric decay mode may be possible if intermediate levels of appropriate spins exist between this level and the ground state. Measured δ⟨r^2⟩(^{218}Fr,^{221}Fr)=−0.401 fm^2 *5* (stat) *6* (syst) (2014Bu06, hyperfine structure using collinear resonance ionization spectroscopy at ISOLDE-CERN). Measured δν(^{218}Fr,^{221}Fr)=+8.24 GHz *10* (2014Bu06, hyperfine structure using collinear resonance ionization spectroscopy at ISOLDE-CERN). E(level): from Eα=7868 *5* and 7952 *5* of 1.1-ms and 21.9-ms α decays, respectively, if they both populate the g.s. in ^{214}At. Jπ: (8$^-$) tentative assignment from 1982Ew01 and 1999Sh03, based on weak population (HF=510) of 9$^-$ isomer at 232 keV in ^{214}At, and fairly strong population (HF=6.8) of an (8$^-$) state at 728 keV in ^{214}At, from α decay of 21.9-ms activity of ^{218}Fr. On the basis of similar configurations, 2014Bu06 suggest that this level may be the same as the 0+x, (9$^-$) in in-beam γ-ray work (2000De36). Evaluators′ shell-model calculations predict 7$^-$ at 82 keV, 8$^-$ at 194 keV, and two 9$^-$ states at 283 and 313 keV. $T_{1/2}$: from α-decay curve; weighted average of 21 ms *2* (2014Bu06) and 22.0 ms *5* (1982Ew01).
112[‡] *28*			B	
163[‡] *28*			B	

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Adopted Levels, Gammas (continued)

^{218}Fr Levels (continued)

E(level)[†]	J$^{\pi}$[#]	XREF	Comments
193[‡] *28*		B	
255[‡] *28*		B	
272.9+x[&]	(11$^-$)	C	
295[‡] *28*		B	
450.0+x[@]	(10$^-$)	C	Evaluators′ shell-model calculations predict 10$^-$ levels at 463 and 492 keV.
550[‡] *28*		B	
586.8+x[a]	(12$^+$)	C	
596.0+x[&]	(13$^-$)	C	
776.6+x[@]	(12$^-$)	C	
862.7+x[a]	(14$^+$)	C	
940.0+x	(13$^+$)	C	
973.1+x[&]	(15$^-$)	C	
1143.8+x[@]	(14$^-$)	C	
1192.1+x[a]	(16$^+$)	C	
1421.7+x[&]	(17$^-$)	C	
1572.4+x[a]	(18$^+$)	C	
1582.9+x[@]	(16$^-$)	C	
1921.7+x[&]	(19$^-$)	C	
2035.1+x[a]	(20$^+$)	C	
2065.1+x[@]	(18$^-$)	C	
2477.9+x[&]	(21$^-$)	C	
2527.5+x[a]	(22$^+$)	C	
3045.1+x[a]	(24$^+$)	C	

† From least-squares fit to Eγ data from (^{18}O,2αnγ), unless otherwise noted.

‡ Level energies are from Eα values measured in 4.9- and 64-s ^{222}Ac decays. The relative energies of the α decaying levels in ^{222}Ac have not been determined. The Eα=7000 *20* from the 64-s isomer and Eα=7008.6 *20* from the 4.9-s g.s. determine the excitation energies of the connecting levels to be very similar: E(level in ^{218}Fr fed from 64-s ^{222}Ac)- E(64-s parent ^{222}Ac level)=9 *21*.

From probable (reflection asymmetric) band assignments for states above the ground state.

@ Band(A): s=−1 band, π=−. Probable configuration=$\pi h_{9/2}\otimes\nu g_{9/2}$.

& Band(B): s=+1 band, π=−. Probable configuration=$\pi h_{9/2}\otimes\nu g_{9/2}$. Average D_0/Q_0=0.00036 fm^{-1} 7, from the γ-ray branching ratios and rotational model, where D_0 and Q_0 are intrinsic electric dipole moment and quadrupole moment, respectively.

^{a} Band(b): s=+1 band, π=+. See comments for the π=− partner of s=+1 band.

γ(^{218}Fr)

E$_i$(level)	J$^{\pi}_i$	E$_\gamma$[†]	I$_\gamma$[†]	E$_f$	J$^{\pi}_f$	Mult.[‡]
272.9+x	(11$^-$)	272.9	100	0+x	(9$^-$)	
450.0+x	(10$^-$)	177.1	100	272.9+x	(11$^-$)	(M1)
586.8+x	(12$^+$)	314.0	100	272.9+x	(11$^-$)	
596.0+x	(13$^-$)	323.0	100	272.9+x	(11$^-$)	
776.6+x	(12$^-$)	326.6	100	450.0+x	(10$^-$)	
862.7+x	(14$^+$)	266.5	100	596.0+x	(13$^-$)	
		275.9	≈10	586.8+x	(12$^+$)	
940.0+x	(13$^+$)	163.5	100	776.6+x	(12$^-$)	
973.1+x	(15$^-$)	110.3	≈20	862.7+x	(14$^+$)	(E1)

Continued on next page (footnotes at end of table)

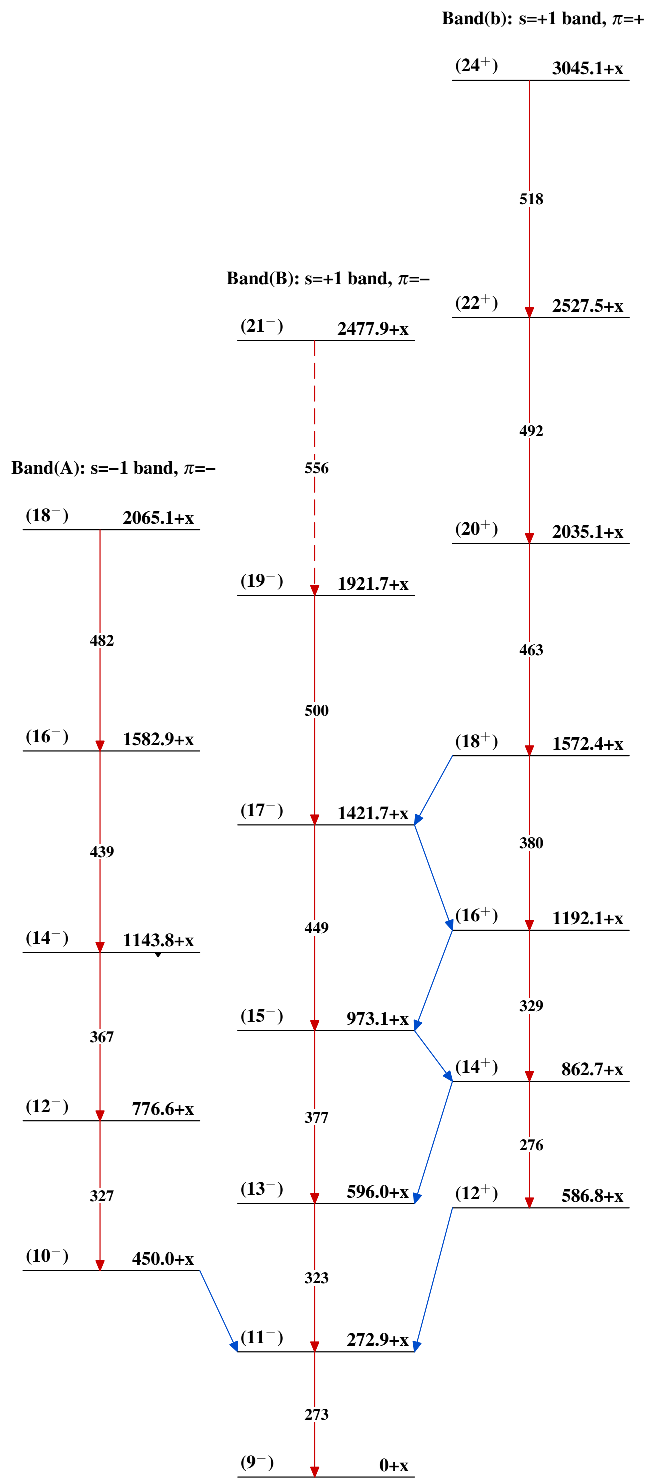
Adopted Levels, Gammas (continued)

$\gamma(^{218}Fr)$ (continued)

E_i(level)	J_i^π	E_γ†	I_γ†	E_f	J_f^π	Mult.‡
973.1+x	(15⁻)	377.2	100	596.0+x	(13⁻)	
1143.8+x	(14⁻)	203.8	≈30	940.0+x	(13⁺)	
		367.1	100	776.6+x	(12⁻)	
1192.1+x	(16⁺)	219.0	100	973.1+x	(15⁻)	
		329.4	≈20	862.7+x	(14⁺)	
1421.7+x	(17⁻)	229.5	100	1192.1+x	(16⁺)	
		448.7	100	973.1+x	(15⁻)	
1572.4+x	(18⁺)	150.6	≈45	1421.7+x	(17⁻)	(E1)
		380.5	100	1192.1+x	(16⁺)	
1582.9+x	(16⁻)	439.1	100	1143.8+x	(14⁻)	
1921.7+x	(19⁻)	500.0	100	1421.7+x	(17⁻)	
2035.1+x	(20⁺)	462.7	100	1572.4+x	(18⁺)	
2065.1+x	(18⁻)	482.2	100	1582.9+x	(16⁻)	
2477.9+x	(21⁻)	556.2§	100	1921.7+x	(19⁻)	
2527.5+x	(22⁺)	492.4	100	2035.1+x	(20⁺)	
3045.1+x	(24⁺)	517.5	100	2527.5+x	(22⁺)	

† From $^{209}Bi(^{18}O,2\alpha n\gamma)$.
‡ From intensity balance in $(^{18}O,2\alpha n\gamma)$.
§ Placement of transition in the level scheme is uncertain.

Adopted Levels, Gammas



$^{218}_{87}Fr_{131}$

^{222}Ac α decay (4.9 s) 1982Bo04,1972Es03,1964Mc21

Parent: ^{222}Ac: E=0.0; $J^\pi=1^-$; $T_{1/2}$=4.9 s *5*; Q(α)=7137.4 *20*; %α decay=99.0 *10*
^{222}Ac-J^π: From ^{222}Ac Adopted Levels in the ENSDF database (March 2011 update).
^{222}Ac-$T_{1/2}$: Weighted average of 5 s *1* (1972Es03), 4.2 s *5* (1958To25) and 5.5 s *5* (1952Me13). Value is 5.0 s *5* in ^{222}Ac Adopted Levels in the ENSDF database.
^{222}Ac-Q(α): From 2017Wa10.
^{222}Ac-%α decay: %α=99 *1*. Possible ε branching was estimated by 1966Wa23 as 1-2% from Iα(7.13-MeV α) of ^{218}Rn shown in ^{222}Ac α spectrum by 1964Mc21. Theoretical partial $T_{1/2}$>100 s for ^{222}Ac $\varepsilon+\beta^+$ decay (2019Mo01) gives (%ε+%β^+)<5.
1982Bo04: measured Eα.
1972Es03: measured Eα, Iα, half-life of decays of ^{222}Ac and ^{218}Fr. Deduced hindrance factors.
1964Mc21: measured Eα, Iα.
Other: 1991Ga28: $\alpha\alpha$ correlations from successive α decays.

^{218}Fr Levels

E(level)	J^π	$T_{1/2}$	Comments
0	1^-	1.1 ms *+5−4*	J^π,$T_{1/2}$: from the Adopted Levels.
46 *11*			

α radiations

Eα	E(level)	Iα[†#]	HF[‡]	Comments
6963 *10*	46	6 *1*	35 *7*	Eα: from 1964Mc21. Original energy has been increased by 11 keV, as recommended by 1991Ry01.
7008.6 *20*	0	94 *1*	3.2 *4*	Eα: recommended by 1991Ry01 from energies measured by 1982Bo04, 1972Es03 and 1964Mc21. The original energies were changed because of changes in calibration energies used. The original energies and the changes (+ for increased energies, and - for decreased Eα) are 7013 *2* (−4.4) (1982Bo04), 7010 *20* (+1.4) (1972Es03), 6998 (−1.6) (1964Mc21). Others: 1988Hu08, 1968Ha14, 1958To25, 1951Me10.

† α intensity per 100 α decays. These Iα data are the values recommended by 1991Ry01 from Iα measured by 1964Mc21.
‡ The nuclear radius parameter $r_0(^{218}Fr)$=1.5497 *30* is deduced from interpolation (or unweighted average) of radius parameters of the adjacent even-even nuclides.
# For absolute intensity per 100 decays, multiply by 0.99 *1*.

^{222}**Ac α decay (64 s)** **1972Es03**

Parent: ^{222}Ac: E=0+x; $T_{1/2}$=64 s *3*; Q(α)=7137.4 *20*; %α decay=94 *6*

^{222}Ac-E: x=9 keV *20*, deduced from Eα=7008.6 *20* and 7000 *20* from the α decays of the 5.0-s and 64-s activities of ^{222}Ac, respectively, both α transitions populating the g.s. of ^{218}Fr. 2017Au03 give 200 keV *150* from systematic trend.

^{222}Ac-$T_{1/2}$: Weighted average of 66 s *3* (1972Es03), 62 s *5* (1973Mo07), 60 s *4* (1982Bo04).

^{222}Ac-J^{π}: On the basis of measured production cross-section ratio, 1972Es03 suggested that the 64-s isomeric state has higher spin than the spin of 4.9-s g.s.

^{222}Ac-Q(α): From 2017Wa10.

^{222}Ac-%α decay: %IT≤10, %ε+%β^+≥0.7≤2 (1972Es03). %IT was deduced by 1972Es03 from ratio of Iα values of 4.9-s ^{222}Ac and 64-s ^{222}Ac. %ε+%β^+ was deduced by 1972Es03 from the intensities of α rays from ^{218}Rn, ^{214}Po and 64-s ^{222}Ac.

1972Es03: measured Eα, Iα, branching ratio.

^{218}Fr Levels

E(level)	J^{π}	$T_{1/2}$	Comments
0.0	1$^-$	1.1 ms *+5−4*	J^{π},$T_{1/2}$: from the Adopted Levels.
31 *28*			
112 *28*			
163 *28*			
193 *28*			
255 *28*			
295 *28*			
550 *28*			

α radiations

Eα†	E(level)	Iα‡@	HF#
6460 *20*	550	2 *1*	15 *8*
6710 *20*	295	8 *4*	40 *21*
6750 *20*	255	15 *5*	30 *11*
6810 *20*	193	27 *10*	29 *12*
6840 *20*	163	10 *5*	101 *53*
6890 *20*	112	15 *5*	105 *38*
6970 *20*	31	8 *3*	3.9×10^2 *16*
7000 *20*	0.0	15 *5*	2.7×10^2 *10*

† From 1972Es03. No adjustment to the energies has been applied.
‡ α intensity per 100 α decays of 64-s ^{222}Ac.
\# The nuclear radius parameter r_0(^{218}Fr)=1.5497 *30* is deduced from interpolation (or unweighted average) of radius parameters of the adjacent even-even nuclides.
@ For absolute intensity per 100 decays, multiply by 0.94 *6*.

^{209}Bi(^{18}O,2αnγ) 2000De36

2000De36: E=94 MeV. Measured Eγ, Iγ, $\gamma\gamma$, $\alpha\gamma\gamma$ coin using the 8π GASP-ISIS spectrometer. Deduced high-spin levels, Jπ, configuration assignments.

^{218}Fr Levels

E(level)[†]	Jπ[‡]	Comments
0+x[@]	(9$^-$)	E(level): it is possible that this level corresponds to 86 keV *8* level with Jπ=(8$^-$,9$^-$) in the Adopted Levels.
272.9+x[@] *5*	(11$^-$)	
450.0+x[#] *7*	(10$^-$)	
586.8+x[&] *7*	(12$^+$)	
596.0+x[@] *7*	(13$^-$)	
776.6+x[#] *9*	(12$^-$)	
862.7+x[&] *7*	(14$^+$)	
940.0+x *10*	(13$^+$)	
973.1+x[@] *8*	(15$^-$)	
1143.8+x[#] *10*	(14$^-$)	
1192.1+x[&] *8*	(16$^+$)	
1421.7+x[@] *8*	(17$^-$)	
1572.5+x[&] *9*	(18$^+$)	
1582.9+x[#] *11*	(16$^-$)	
1921.7+x[@] *10*	(19$^-$)	
2035.2+x[&] *10*	(20$^+$)	
2065.1+x[#] *12*	(18$^-$)	
2477.9+x[@] *12*	(21$^-$)	
2527.6+x[&] *11*	(22$^+$)	
3045.1+x[&] *12*	(24$^+$)	

† From least-squares fit to Eγ data, assuming Δ(Eγ)=0.3 keV for each Eγ.

‡ From probable (reflection asymmetric) band assignments for states other than the ground state. The assignments are the same in the Adopted Levels.

Band(A): s=−1 band, π=−. Probable configuration=$\pi h_{9/2}\otimes\nu g_{9/2}$.

@ Band(B): s=+1 band, π=−. Probable configuration=$\pi h_{9/2}\otimes\nu g_{9/2}$. Average (D$_0$/Q$_0$)=0.00036 fm^{-1} 7, from the γ-ray branching ratios and rotational model, where D$_0$ and Q$_0$ are intrinsic electric dipole moment and quadrupole moment, respectively.

& Band(b): s=+1 band, π=+. See comment for the π=− partner of s=+1 band.

γ(^{218}Fr)

Eγ	Iγ[‡]	E$_i$(level)	J$^\pi_i$	E$_f$	J$^\pi_f$	Mult.[§]	α[@]	I$_{(\gamma+ce)}$[†]	Comments
110.3	11	973.1+x	(15$^-$)	862.7+x	(14$^+$)	(E1)[&]	0.372	15	
150.6	13	1572.5+x	(18$^+$)	1421.7+x	(17$^-$)	(E1)[&]	0.1750	15	
163.5	2.6	940.0+x	(13$^+$)	776.6+x	(12$^-$)	[E1]	0.1433	3	
177.1	3.9	450.0+x	(10$^-$)	272.9+x	(11$^-$)	(M1)[&]	2.82	15	Mult.: small E2 admixture is also possible.
203.8	2.8	1143.8+x	(14$^-$)	940.0+x	(13$^+$)	[E1]	0.0843	3	
219.0	42	1192.1+x	(16$^+$)	973.1+x	(15$^-$)	[E1]	0.0710	45	
229.5	14	1421.7+x	(17$^-$)	1192.1+x	(16$^+$)	[E1]	0.0636	15	
266.5	29	862.7+x	(14$^+$)	596.0+x	(13$^-$)	[E1]	0.0448	30	
272.9	84	272.9+x	(11$^-$)	0+x	(9$^-$)	[E2]	0.194	100	
275.9	2.5	862.7+x	(14$^+$)	586.8+x	(12$^+$)	[E2]	0.187	3	

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^{209}Bi(^{18}O,2αnγ) 2000De36 (continued)

γ(^{218}Fr) (continued)

E_γ	I_γ ‡	E_i(level)	J_i^π	E_f	J_f^π	Mult.§	α@	$I_{(\gamma+ce)}$ †
314.0	4.9	586.8+x	(12$^+$)	272.9+x	(11$^-$)	[E1]	0.0309	5
323.0	81	596.0+x	(13$^-$)	272.9+x	(11$^-$)	[E2]	0.1163	90
326.6	13	776.6+x	(12$^-$)	450.0+x	(10$^-$)	[E2]	0.1126	15
329.4	9	1192.1+x	(16$^+$)	862.7+x	(14$^+$)	[E2]	0.1099	10
367.1	9.3	1143.8+x	(14$^-$)	776.6+x	(12$^-$)	[E2]	0.0810	10
377.2	56	973.1+x	(15$^-$)	596.0+x	(13$^-$)	[E2]	0.0753	60
380.5	28	1572.5+x	(18$^+$)	1192.1+x	(16$^+$)	[E2]	0.0735	30
439.1	9.5	1582.9+x	(16$^-$)	1143.8+x	(14$^-$)	[E2]	0.0506	10
448.7	14	1421.7+x	(17$^-$)	973.1+x	(15$^-$)	[E2]	0.0480	15
462.7	29	2035.2+x	(20$^+$)	1572.5+x	(18$^+$)	[E2]	0.0445	30
482.2	2.9	2065.1+x	(18$^-$)	1582.9+x	(16$^-$)	[E2]	0.0402	3
492.4	19	2527.6+x	(22$^+$)	2035.2+x	(20$^+$)	[E2]	0.0382	20
500.0	9.6	1921.7+x	(19$^-$)	1421.7+x	(17$^-$)	[E2]	0.0369	10
517.5	4.8	3045.1+x	(24$^+$)	2527.6+x	(22$^+$)	[E2]	0.0340	5
556.2#	2.9	2477.9+x	(21$^-$)	1921.7+x	(19$^-$)	[E2]	0.0288	3

† Numerical values not given by 2000De36. Values listed here are estimates (by the evaluators) from thickness of arrows in the level-scheme figure 2 of 2000De36, and are assumed as the transition intensities i.e. I(γ+ce).

‡ Deduced by evaluators from I(γ+ce) and α(theory).

§ 2000De36 assumed intraband transitions as stretched E2 transitions based on systematics of neighboring nuclides such as ^{217}Fr, ^{219}Ra, ^{220}Ac, etc. The interband transitions of 219.0, 229.5 and 266.5 keV were assumed as E1. No angular correlation or conversion data are yet available to confirm these assignments.

& From estimated intensity balance.

@ Total theoretical internal conversion coefficients, calculated using the BrIcc code (2008Ki07) with Frozen orbital approximation based on γ-ray energies, assigned multipolarities, and mixing ratios, unless otherwise specified.

Placement of transition in the level scheme is uncertain.

Adopted Levels, Gammas

Q(β^-)=−4190 *50*; S(n)=7310 *13*; S(p)=4952 *13*; Q(α)=8546 *6* 2017Wa10
S(2n)=12783 *14*, S(2p)=8180 *13* (2017Wa10).
Theory references: consult NSR database (www.nndc.bnl.gov/nsr/) for 62 primary references for nuclear structure, and 42 for calculations of half-lives of radioactive decays.
From lifetime measurements, 1988Ga33 conclude that higher spin states exhibit enhanced B(E1) rates of about 0.006 which may be a result of collective dipole deexcitations from a reflection- asymmetric intrinsic state.

^{218}Ra Levels

Cross Reference (XREF) Flags

A ^{222}Th α decay (1.964 ms)
B ^{208}Pb(^{13}C,3nγ),(^{14}C,4nγ),^{13}C(^{208}Pb,3nγ)

E(level)[†]	J$^{\pi}$[‡]	T$_{1/2}$[#]	XREF	Comments
0.0	0+	25.91 μs *14*	AB	%α=100 T$_{1/2}$: weighted average of 25.99 μs *10* (E. Parr et al., Phys Rev. C 100, 044323 (2019)), 25.2 μs *3* (2001Ku07), 26 μs *2* (1992Wi14) and 25.6 μs *11* (1986To02). Others: 15.6 μs *10* (1991AnZZ), 14 μs *2* (1970Va13).
388.90[&] *10*	2+	29.8 ps *28*	AB	J$^{\pi}$: E2 γ to 0+.
741.10[&] *14*	4+	19.4 ps *35*	B	J$^{\pi}$: ΔJ=2, E2 γ to 2+.
793.21[a] *18*	(3−)		AB	J$^{\pi}$: ΔJ=1, D γ to 2+.
853[a] *6*	(1−)		A	E(level): from Eα and Q(α) values. J$^{\pi}$: on the basis of the similarity in the hindrance factor for the 853 level with that of the 793 level, and the γ to 0+, 2016Pa28 propose that the 853 level is the bandhead of the octupole band.
1038.32[a] *18*	5−		B	J$^{\pi}$: ΔJ=1, E1 γ to 4+.
1122.04[&] *20*	6+	13.2 ps *28*	B	J$^{\pi}$: ΔJ=2, E2 γ to 4+; E1 γ to 5−.
1340.85[a] *21*	7−	[@]	B	J$^{\pi}$: ΔJ=1, E1 γ to 6+; ΔJ=2, E2 γ to 5−.
1546.70[&] *23*	8+	[@]	B	J$^{\pi}$: ΔJ=1, E1 γ to 7−; ΔJ=2, E2 γ to 6+.
1573.01 *19*	(3−,4,5−)		B	J$^{\pi}$: γ rays to (3−) and 5−.
1694.35[a] *25*	9−	[@]	B	J$^{\pi}$: γ to 8+; ΔJ=2, E2 γ to 7−.
1714.60 *25*			B	J$^{\pi}$: γ to 4+.
1725.8 *3*			B	J$^{\pi}$: γ to 5−.
1803.60 *24*			B	J$^{\pi}$: γ rays to 6+ and 7−.
1855.9 *3*			B	J$^{\pi}$: γ to 6+.
1896.8 *3*			B	J$^{\pi}$: γ to 8+.
1961.7[&] *3*	10+	[@]	B	J$^{\pi}$: ΔJ=1, E1 γ to 9−; ΔJ=2, E2 γ to 8+.
2031.8 *3*			B	J$^{\pi}$: γ to 9−.
2109.3[a] *3*	11−	[@]	B	J$^{\pi}$: ΔJ=2, E2 γ to 9−; ΔJ=1, D γ to 10+.
2328.3 *4*			B	
2390.8[&] *3*	12+	<1.4 ps	B	J$^{\pi}$: ΔJ=1, E1 γ to 11−; ΔJ=2, E2 γ to 10+.
2420.0[b] *3*	(12−)		B	J$^{\pi}$: ΔJ=1, (M1+E2) γ to 11−.
2442.4 *4*			B	
2465.6 *3*			B	J$^{\pi}$: γ to 10+.
2526.3[a] *3*	13−	<4.9 ps	B	J$^{\pi}$: ΔJ=1, E1 γ to 12+; ΔJ=2, E2 γ to 11−.
2825.5[&] *3*	14+	<1.4 ps	B	J$^{\pi}$: ΔJ=1, E1 γ to 13−; ΔJ=2, E2 γ to 12+.
2966.4[a] *4*	15−	<1.4 ps	B	J$^{\pi}$: ΔJ=1, E1 γ to 14+; ΔJ=2, E2 γ to 13−. T$_{1/2}$: This T$_{1/2}$ leads to B(E2)(W.u)>218, a factor of about 3 larger than any of the other E2 or E1 reduced transition probabilities. The T$_{1/2}$ limit may be a typo.
2967.2[b] *4*	(14−)		B	J$^{\pi}$: ΔJ=2, E2 γ to (12−); γ to 13−.
3285.1[&] *4*	16+		B	J$^{\pi}$: γ rays to 14+ and 15−.

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Adopted Levels, Gammas (continued)

^{218}Ra Levels (continued)

E(level)[†]	J^π[‡]	$T_{1/2}$[#]	XREF	Comments
3387.7[b] *7*	(16⁻)		B	J^π: γ to (14⁻).
3388.8[a] *4*	17⁻	<13 ps	B	J^π: ΔJ=2, E2 γ to 15⁻; γ to 16⁺.
3719.8[b] *7*	(18⁻)		B	J^π: γ rays to (16⁻) and 17⁻.
3756.0[&] *7*	18⁺		B	J^π: γ to 17⁻, and member of g.s. band.
3805.9[a] *8*	19⁻		B	J^π: γ rays to 17⁻, (18⁻) and 18⁺.
4117.7[b] *9*	(20⁻)		B	J^π: γ rays to (18⁻) and 19⁻.
4191.1?[&] *11*	(20⁺)		B	J^π: γ rays to 18⁺ and 19⁻.
4212.6[a] *10*	(21⁻)		B	J^π: γ to 19⁻.
4391.6[c] *11*	(21⁺)		B	J^π: γ to (20⁻).
4588.3[&] *11*	(22⁺)		B	J^π: γ to (21⁻).
4675.3[a] *10*	(23⁻)		B	J^π: γ rays to (21⁻) and (22⁺).
4682.6[b] *10*	(22⁻)		B	J^π: γ rays to (20⁻) and (21⁻).
4835.5[c] *11*	(23⁺)		B	J^π: γ rays to (21⁺), (22⁺) and (22⁻).
5020.3[&] *12*	(24⁺)		B	J^π: γ rays to (22⁺) and (23⁻).
5125.4[a] *13*	(25⁻)		B	J^π: γ rays to (23⁻) and (24⁺).
5139.4[b] *11*	(24⁻)		B	J^π: γ rays to (22⁻) and (23⁺).
5363.5[c] *13*	(25⁺)		B	J^π: γ rays to (23⁺) and (24⁻).
5470.1[&] *13*	(26⁺)		B	J^π: γ rays to (24⁺) and (25⁻).
5588.1[a] *13*	(27⁻)		B	J^π: γ rays to (25⁻) and (26⁺).
5901.7[&] *14*	(28⁺)		B	J^π: γ rays to (26⁺) and (27⁻).
6134.9[a] *15*	(29⁻)		B	J^π: γ rays to (27⁻) and (28⁺).
6343.8[&] *15*	(30⁺)		B	J^π: γ rays to (28⁺) and (29⁻).
6678.8[a] *16*	(31⁻)		B	J^π: γ rays to (29⁻) and (30⁺).

† From a least-squares fit to the adopted Eγ data except for the 853 level which comes from the E(α) branch to that level.
‡ From $\gamma(\theta)$ and γ(lin pol) data in ^{208}Pb(^{13}C,3nγ), and association of levels in bands or sequences. Additional γ mult arguments are given explicitly.
# From recoil-distance Doppler-shift method in inverse kinematic reaction: ^{13}C(^{208}Pb,3nγ)(1988Ga33). No delayed component with a half-life longer than 5 ns was observed for any of the transitions (1986Go21).
@ 1988Ga33 deduced $T_{1/2}$=3.1 ps *4* for 1341, 7⁻; 2.3 ps *3* for 1547, 8⁺; 5.9 ps *6* for 1694, 9⁻; 2.6 ps *4* for 1962, 10⁺; and 4.2 ps *5* for 2109, 11⁻ levels using average B(E2) for transitions from some of the above levels.
& Band(A): Kπ=0⁺ g.s. band.
a Band(B): Octupole band.
b Seq.(C): γ sequence based on 12⁻.
c Seq.(D): γ sequence based on (21⁺).

γ(^{218}Ra)

E_i(level)	J^π_i	E_γ[†]	I_γ[†]	E_f	J^π_f	Mult.[‡]	α[§]	Comments
388.90	2⁺	388.9 *1*	100	0.0	0⁺	E2	0.0727	B(E2)(W.u.)=25.5 *24*
741.10	4⁺	352.2 *1*	100	388.90	2⁺	E2	0.0954	B(E2)(W.u.)=63 *12*
793.21	(3⁻)	404.3 *2*	100	388.90	2⁺	D		
853	(1⁻)	853		0.0	0⁺			
1038.32	5⁻	245.1 *2*		793.21	(3⁻)			
		297.3 *2*		741.10	4⁺	E1	0.0359	
1122.04	6⁺	83.7 *2*	35 *7*	1038.32	5⁻	(E1)	0.177 *3*	B(E1)(W.u.)=0.0057 *17*
		380.9 *2*	100 *6*	741.10	4⁺	E2	0.0769	B(E2)(W.u.)=46 *11*

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Adopted Levels, Gammas (continued)

$\gamma(^{218}Ra)$ (continued)

E_i(level)	J^π_i	E_γ†	I_γ†	E_f	J^π_f	Mult.‡	α§	Comments
1340.85	7⁻	218.8 *1*	100 *5*	1122.04	6⁺	E1	0.0729	
		302.6 *2*	8.7 *22*	1038.32	5⁻	E2	0.1482	
1546.70	8⁺	205.8 *2*	100 *7*	1340.85	7⁻	E1	0.0843	
		424.6 *2*	71 *20*	1122.04	6⁺	E2	0.0578	
1573.01	(3⁻,4,5⁻)	534.7 *2*		1038.32	5⁻			
		779.8 *2*		793.21	(3⁻)			
		831.9 *2*		741.10	4⁺			
1694.35	9⁻	147.5@ *2*	100@ *45*	1546.70	8⁺		0.190	
		353.6 *2*	58 *20*	1340.85	7⁻	E2	0.0943	
1714.60		973.5 *2*		741.10	4⁺			
1725.8		687.5 *2*	100	1038.32	5⁻			
1803.60		462.7 *2*		1340.85	7⁻			
		681.6 *2*		1122.04	6⁺			
1855.9		733.9 *2*	100	1122.04	6⁺			
1896.8		350.1 *2*	100	1546.70	8⁺			
1961.7	10⁺	267.3 *1*	100 *5*	1694.35	9⁻	E1	0.0457	
		415.0@ *2*	36@ *9*	1546.70	8⁺	E2	0.0613	
2031.8		337.5 *2*	100	1694.35	9⁻			
2109.3	11⁻	77.5 *2*		2031.8				
		147.5@ *2*	42@ *42*	1961.7	10⁺		0.190	
		415.0@ *2*	100@ *25*	1694.35	9⁻	E2	0.0613	
2328.3		472.4 *2*	100	1855.9				
2390.8	12⁺	281.4 *2*	100 *7*	2109.3	11⁻	E1	0.0407	B(E1)(W.u.)>0.004
		429.3 *2*	33 *7*	1961.7	10⁺	E2	0.0562	B(E2)(W.u.)>84
2420.0	(12⁻)	310.6 *2*	100	2109.3	11⁻	(M1+E2)	0.4 *3*	
2442.4		410.6 *2*	100	2031.8				
2465.6		503.9 *2*		1961.7	10⁺			
		568.8 *2*		1896.8				
2526.3	13⁻	106.1 *2*		2420.0	(12⁻)			
		135.6 *2*	33 *3*	2390.8	12⁺	E1	0.230	B(E1)(W.u.)>0.0034
		416.9 *2*	100 *27*	2109.3	11⁻	E2	0.0606	B(E2)(W.u.)>80
2825.5	14⁺	299.3 *2*	100 *28*	2526.3	13⁻	E1	0.0354	B(E1)(W.u.)>0.0035
		434.8& *2*	<45	2390.8	12⁺	E2	0.0544	E_γ: double placement, with intensity not divided.
2966.4	15⁻	140.9 *2*	32 *5*	2825.5	14⁺	E1	0.210	B(E1)(W.u.)>0.011
		440.0 *2*	100 *5*	2526.3	13⁻	E2	0.0528	B(E2)(W.u.)>218
2967.2	(14⁻)	142		2825.5	14⁺			
		440.8 *2*		2526.3	13⁻			
		547.3 *2*		2420.0	(12⁻)	E2	0.0313	
3285.1	16⁺	318.7	100 *20*	2966.4	15⁻			
		459.7	60 *20*	2825.5	14⁺			
3387.7	(16⁻)	420.5	100	2967.2	(14⁻)			
3388.8	17⁻	104		3285.1	16⁺			
		422.4 *2*		2966.4	15⁻	E2	0.0586	
3719.8	(18⁻)	331		3388.8	17⁻			
		332.1 *3*		3387.7	(16⁻)			
3756.0	18⁺	367		3388.8	17⁻			
		471#		3285.1	16⁺			
3805.9	19⁻	50		3756.0	18⁺			
		86		3719.8	(18⁻)			
		417		3388.8	17⁻			
4117.7	(20⁻)	312		3805.9	19⁻			
		398		3719.8	(18⁻)			

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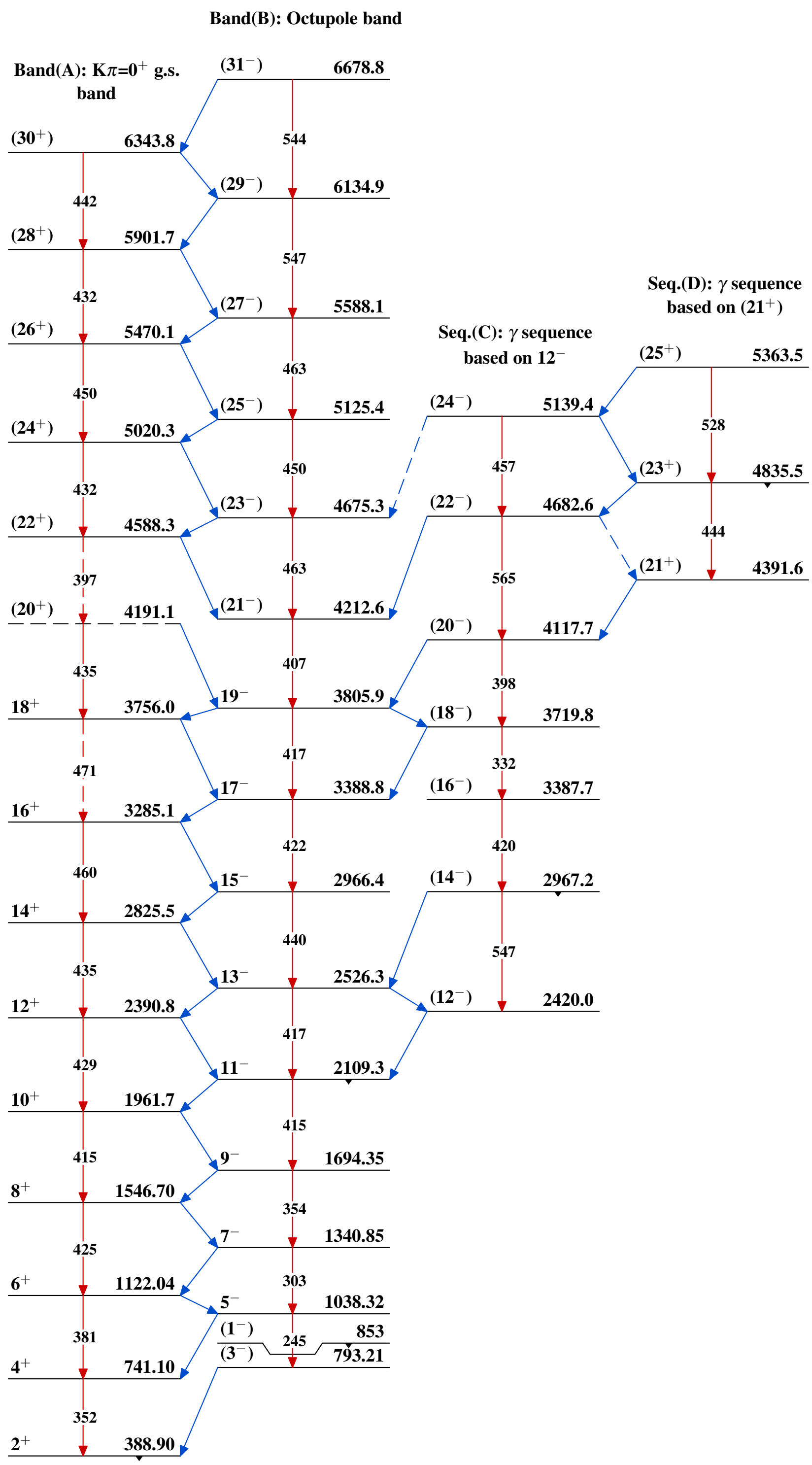
Adopted Levels, Gammas (continued)

$\gamma(^{218}Ra)$ (continued)

E_i(level)	J^π_i	E_γ†	I_γ†	E_f	J^π_f	Comments
4191.1?	(20+)	385		3805.9	19−	
		434.8& 2		3756.0	18+	E_γ: double placement, with intensity not divided.
4212.6	(21−)	406.6	100	3805.9	19−	
4391.6	(21+)	274	100	4117.7	(20−)	
4588.3	(22+)	376		4212.6	(21−)	
		397#		4191.1?	(20+)	
4675.3	(23−)	87		4588.3	(22+)	
		462.7&		4212.6	(21−)	
4682.6	(22−)	291#		4391.6	(21+)	
		470		4212.6	(21−)	
		565		4117.7	(20−)	
4835.5	(23+)	153		4682.6	(22−)	
		247		4588.3	(22+)	
		444		4391.6	(21+)	
5020.3	(24+)	345&		4675.3	(23−)	
		432&		4588.3	(22+)	
5125.4	(25−)	105		5020.3	(24+)	
		450&		4675.3	(23−)	
5139.4	(24−)	304		4835.5	(23+)	
		457		4682.6	(22−)	
		464#		4675.3	(23−)	
5363.5	(25+)	224		5139.4	(24−)	
		528		4835.5	(23+)	
5470.1	(26+)	345&		5125.4	(25−)	
		450&		5020.3	(24+)	
5588.1	(27−)	118		5470.1	(26+)	
		463&		5125.4	(25−)	
5901.7	(28+)	313		5588.1	(27−)	
		432&		5470.1	(26+)	
6134.9	(29−)	233		5901.7	(28+)	
		547		5588.1	(27−)	
6343.8	(30+)	209		6134.9	(29−)	
		442		5901.7	(28+)	
6678.8	(31−)	335		6343.8	(30+)	
		544		6134.9	(29−)	

† From $^{208}Pb(^{13}C,3n\gamma),(^{14}C,4n\gamma)$ dataset.
‡ From $\gamma(\theta)$ and γ(lin pol) data in $^{208}Pb(^{13}C,3n\gamma)$.
§ Total theoretical internal conversion coefficients, calculated using the BrIcc code (2008Ki07) with Frozen orbital approximation based on γ-ray energies, assigned multipolarities, and mixing ratios, unless otherwise specified.
& Multiply placed.
@ Multiply placed with intensity suitably divided.
# Placement of transition in the level scheme is uncertain.

Adopted Levels, Gammas



$^{218}_{88}Ra_{130}$

^{222}Th α decay (1.964 ms) 2001Ku07,2016Pa28

Parent: ^{222}Th: E=0.0; $J^{\pi}=0^{+}$; $T_{1/2}$=1.964 ms *2*; Q(α)=8127 *5*; %α decay=100.0

^{222}Th-$T_{1/2}$: From 2016Pa28. Others (in ms): 2.4 *3* (2005Li17), 2.237 *13* (2001Ku07), 2.0 *1* (2000He17), 4.2 *5* (1999Ho28), 2.2 *2* (1991AnZZ), 2.8 *3* (1970Va13), 4 *1* (1970To07). Precise value from 2001Ku07 (a conference report), and value from 1999Ho28 are in severe disagreement with that from 2016Pa28, the former differing by ≈20 standard deviations. Note that the three measurements are from JYFL facility at the University of Jyvaskyla with several of the same authors. For this reason, values from 2001Ku07 and 1999Ho28 are not considered here. Other values are in agreement, but are too imprecise to be considered for averaging.

^{222}Th-Q(α): From 2017Wa10.

^{222}Th-%α decay: %α=100. %$\varepsilon<1.3\times10^{-8}$, estimated by evaluators from a possible ε branch to ^{222}Ac g.s., with log *ft*>5.9. Theoretical partial $T_{1/2}$>100 s for ^{222}Th ε decay (2019Mo01) gives %ε<0.002, and theoretical partial $T_{1/2}\approx8\times10^{+4}$ s of 1973Ta30 gives %$\varepsilon\approx3\times10^{-6}$.

^{218}Ra Levels

E(level)	J^{π}†	$T_{1/2}$†	Comments
0.0	0^+	25.2 μs *3*	
389.5 *5*	2^+		E(level): from Eγ.
790 *6*	(3^-)		E(level): from Eα and Q(α) values.
853 *6*	(1^-)		E(level): from Eα and Q(α) values. E(level): on the basis of the γ to g.s. and the similarity in the α hindrance factors for the 793 and 853 levels, 2016Pa28 propose that the 853 level is a member of the octupole band. The energy inversion of the 1^- and 3^- members of this band supports an octupole-vibration description of the band, 1992Wi14 looked for but did not find any evidence for levels between the 3^- at 793 and the 2^+ at 389.

† From the Adopted Levels.

α radiations

Eα	E(level)	Iα‡	HF†	Comments
7143 *4*	853	0.014 *4*	12 *4*	Eα,Iα: from 2016Pa28.
7205 *4*	790	0.018 *3*	15 *3*	Eα,Iα: from 2016Pa28.
7600 *2*	389.5	1.81 *1*	3.38 *6*	Eα: from the weighted average of 7603 *3* (2016Pa28), 7599 *2* (2001Ku07), 7600 *15* (1991An13). Iα: from 2016Pa28. Others 2.3 *2* (2001Ku07), 3 *1* (1991An13).
7982 *2*	0.0	98.16 *5*	1.00	Eα: from the weighted average of 7986 *3* (2016Pa28), 7980 *2* (2001Ku07), 7970 *48* (2005Li17), 7974 *10* (2000He17), 7980 *15* (1991An13), 7984 *8* (1970To07), 7980 *10* (1970Va13). Iα: From 2016Pa28, other: 97.7 *9* (2001Ku07), 97 *1* (1991An13).

† HF(7982α)=1.0 yields r_0(^{218}Ra)=1.5571 *17*.

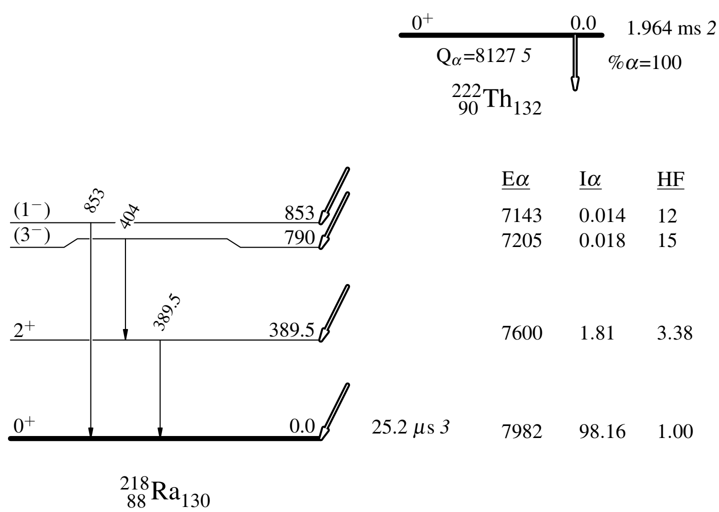
‡ Absolute intensity per 100 decays.

γ(^{218}Ra)

E_{γ}	E_i(level)	J_i^{π}	E_f	J_f^{π}	Comments
389.5 *5*	389.5	2^+	0.0	0^+	E_{γ}: from 2001Ku07.
404	790	(3^-)	389.5	2^+	E_{γ}: from in beam studies (1992Wi14, 1983Ga11).
853	853	(1^-)	0.0	0^+	E_{γ}: from 2016Pa28.

^{222}Th α decay (1.964 ms) 2001Ku07,2016Pa28

Decay Scheme



^{208}Pb(^{13}C,3nγ),(^{14}C,4nγ),^{13}C(^{208}Pb,3nγ) 1989Sc33,1986Go21,1982Fe04

1989Sc33 (also 1989Va22): ^{208}Pb(^{14}C,4nγ) E=80 MeV. Measured Eγ, γγ, γγ(t). The g.s. band up to 30$^+$; octupole band from 5$^-$ to 31$^-$; a band based on 12$^-$ (up to 24$^-$); and four other levels.
1988Ga33: ^{13}C(^{208}Pb,3nγ) E(^{208}Pb)=5.31 MeV/nucleon. Measured lifetimes by recoil-distance Doppler-shift method.
1986Go21: ^{208}Pb(^{13}C,3nγ) E=75 MeV. Measured Eγ, Iγ, γγ, γγ(θ). The g.s. band up to 16$^+$; octupole band from 5$^-$ to 21$^-$; a cascade of 3 transitions based on 13$^-$.
1982Fe04: ^{208}Pb(^{13}C,3nγ) E=60-83 MeV. Measured Eγ, Iγ, γ(θ,t), γ(lin pol), γγ.
1992Wi14: ^{208}Pb(^{13}C,3nγ) E=61 MeV. Measured Eγ, γγ, γγ(θ)(DCO), γα(t) using an array of 12 Compton-suppressed Ge detectors combined with an array of 26 BaF_2 counters as multiplicity filter. Pulsed beam for delayed coin measurements.
1983Ga11 (also comment about 1$^-$ state by 1993Ga17): ^{208}Pb(^{13}C,3nγ) E=59, 59.5, 67 MeV. Measured Eγ, γγ, γ(θ), αγ(t), γ and α excitation functions, $T_{1/2}$ by Doppler-shift recoil-distance method. The g.s. band up to 16$^+$; octupole band from 3$^-$ to 17$^-$.
The level scheme given here is mainly that of 1989Sc33. The main two bands of the level scheme were constructed in their earlier work, 1982Fe04; with subsequent confirmation by 1983Ga11 and 1986Go21, except with the revised ordering of the 389-352 cascade. The 3$^-$ member of the negative-parity band was assigned by 1983Ga11 and confirmed by 1992Wi14.
From lifetime measurements, 1988Ga33 conclude that higher spin states exhibit enhanced B(E1) rates of about 0.006 which may be a result of collective dipole deexcitations from a reflection- asymmetric intrinsic state.

^{218}Ra Levels

E(level)[†‡]	Jπ[#]	$T_{1/2}$[@]	Comments
0.0[b]	0+		
388.90[b] *10*	2+	29.8 ps *28*	$T_{1/2}$: other: 9.5 ps *24* from B(E2)(W.u.)=80 *20* (1983Ga11); E(level): 1982Fe04 suggested a different order for the 352-382 cascade from the 741 level placing the first excited level at 352.2. The order here is from 1983Ga11 and later papers.
741.10[b] *14*	4+	19.4 ps *35*	
793.21[c] *18*	(3−)		E(level): from 1992Wi14.
1038.32[c] *18*	5−		
1122.04[b] *20*	6+	13.2 ps *28*	
1340.85[c] *21*	7−	[a]	
1546.70[b] *23*	8+	[a]	
1573.01 *19*			
1694.35[c] *25*	9−	[a]	
1714.60 *25*			
1725.8 *3*			
1803.60 *24*			
1855.9 *3*			
1896.8 *3*			
1961.7[b] *3*	10+	[a]	
2031.8 *3*	(10+)		Jπ: 1989Sc33 suggest (10)+.
2109.3[c] *3*	11−	[a]	
2328.3 *4*			
2390.8[b] *3*	12+	<1.4[&] ps	
2420.0[d] *3*	12−		
2442.4 *4*	(10+)		
2465.6 *3*			
2526.3[c] *3*	13−	<4.9[&] ps	
2825.5[b] *3*	14+	<1.4[&] ps	
2966.4[c] *4*	15−	<1.4[&] ps	
2967.2[d] *4*	14−		
3285.1[b] *4*	16+		
3387.7[d] *7*	16−		
3388.8[c] *4*	17−	<13 ps	$T_{1/2}$: 11.8 ps *14* (combined level half-life and feeding time,1988Ga33).

Continued on next page (footnotes at end of table)

^{208}Pb(^{13}C,3nγ),(^{14}C,4nγ),^{13}C(^{208}Pb,3nγ) 1989Sc33,1986Go21,1982Fe04 (continued)

^{218}Ra Levels (continued)

E(level)[†‡]	Jπ[#]	E(level)[†‡]	Jπ[#]	E(level)[†‡]	Jπ[#]	E(level)[†‡]	Jπ[#]
3719.8[d] 7	18⁻	4391.6[e] 11	(21⁺)	5125.4[c] 13	25⁻	6134.9[c] 15	(29⁻)
3756.0[b] 7	18⁺	4588.3[b] 11	22⁺	5139.4[d] 11	(24⁻)	6343.8[b] 15	(30⁺)
3805.9[c] 8	19⁻	4675.3[c] 10	23⁻	5363.5[e] 13	(25⁺)	6678.8[c] 16	(31⁻)
4117.7[d] 9	20⁻	4682.6[d] 10	22⁻	5470.1[b] 13	(26⁺)		
4191.1?[b] 11	(20⁺)	4835.5[e] 11	(23⁺)	5588.1[c] 13	27⁻		
4212.6[c] 10	21⁻	5020.3[b] 12	(24⁺)	5901.7[b] 14	(28⁺)		

[†] From a least-squares fit to the Eγ values. When not stated, uncertainties are assumed as 0.3 keV for Eγ quoted to the nearest tenth of a keV, and 1 keV for Eγ quoted to the nearest keV;

[‡] In addition to the levels listed here, 1983Ga11 propose tentative levels at 974 (0^+), 1072 (2^+) and 1123 (4^+) deexciting via 585, 683, and 734 γ rays respectively to the 389 2^+ level, and tentative levels at 2657, 2968, and 3299 deexciting via 547, 311, and 331 γ rays, respectively. These levels are not confirmed by later work. 1983Ga11 also show a tentative level at 713 deexciting via a 324 γ to the 2^+ level which they suggest as the 1^- member of the octupole band. This level has also not been confirmed.

[#] Mostly from 1989Sc33. Below 17^-, the assignments are based on γ(θ) and γ(lin pol) data of 1982Fe04 and angular correlation data from some later works, although the values of angular correlation coefficients are not provided in these later papers. The assignments are the same in 'Adopted Levels', except that parentheses are added in cases where strong arguments for Jπ assignments are lacking.

[@] From recoil-distance Doppler-shift method (1988Ga33). No delayed component with a half-life longer than 5 ns was observed for any of the transitions (1986Go21).

[&] Only a limit can be determined since the level is fed by a relatively long-lived state (1988Ga33).

[a] 1988Ga33 deduced $T_{1/2}$=3.1 ps *4* for 1341, 7^-; 2.3 ps *3* for 1547, 8^+; 5.9 ps *6* for 1694, 9^-; 2.6 ps *4* for 1962, 10^+; and 4.2 ps *5* for 2109, 11^- levels using average B(E2) for transitions from some of the above levels. The B(E2) values were presumably deduced from measured fractional time decay curves for transitions from 7^- to 6^+, 8^+ to 7^- and 10^+ to 8^+ levels, as shown in authors′ Fig. 1.

[b] Band(A): Kπ=0^+ g.s. band.

[c] Band(B): Octupole band.

[d] Seq.(C): γ sequence based on 12^-.

[e] Seq.(D): γ sequence based on (21^+).

γ(^{218}Ra)

Measured values of A_2, A_4 and POL are from 1982Fe04.

$E_γ$[†‡]	$I_γ$[§]	E_i(level)	$J^π_i$	E_f	$J^π_f$	Mult.[&]	α[b]	Comments
50		3805.9	19⁻	3756.0	18⁺			
77.5 2		2109.3	11⁻	2031.8	(10⁺)			
83.7 2	25 5	1122.04	6⁺	1038.32	5⁻	E1	0.177 3	Mult.: Mult(83.7γ)>E1 would yield unreasonably large transition intensity (1982Fe04). $I_γ$: from I(γ)(83.7γ)/I(γ)(380.9γ)=25 *5*/71 *3* (1982Fe04).
86		3805.9	19⁻	3719.8	18⁻			
87		4675.3	23⁻	4588.3	22⁺			
104		3388.8	17⁻	3285.1	16⁺			
105		5125.4	25⁻	5020.3	(24⁺)			
106.1 2		2526.3	13⁻	2420.0	12⁻			
118		5588.1	27⁻	5470.1	(26⁺)			
135.6 2	10 1	2526.3	13⁻	2390.8	12⁺	E1	0.230	A_2=−0.22 *14*; A_4=+0.14 *19*; pol=+0.37 *12*
140.9 2	7 1	2966.4	15⁻	2825.5	14⁺	E1	0.210	A_2=−0.31 *12*; A_4=+0.12 *14*; pol=+0.31 *14*

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^{208}Pb(^{13}C,3nγ),(^{14}C,4nγ),^{13}C(^{208}Pb,3nγ) 1989Sc33,1986Go21,1982Fe04 (continued)

γ(^{218}Ra) (continued)

Eγ[†‡]	Iγ[§]	Ei(level)	$J^π_i$	E_f	$J^π_f$	Mult.[&]	α[b]	Comments
								1982Fe04 report I(γ)(140.9γ)/I(γ)(440.0γ)=0.65 *9*, which gives I(γ)(140.9)=17 *2*; This ratio in 1986Go21, and 1983Ga11 is 0.32 *5* and 0.20, respectively.
142		2967.2	14⁻	2825.5	14⁺			
147.5[e] *2*	36[e] *16*	1694.35	9⁻	1546.70	8⁺	(E1)	0.188	A_2=−0.33 *4*; A_4=−0.06 *7*; pol=+0.27 *5* A_2, A_4 and POL for unresolved doublet.
147.5[e] *2*	14[e] *14*	2109.3	11⁻	1961.7	10⁺	(E1)	0.188	
153		4835.5	(23⁺)	4682.6	22⁻			
205.8 *2*	31 *2*	1546.70	8⁺	1340.85	7⁻	E1	0.0843	A_2=−0.25 *8*; A_4=+0.02 *5*; pol=+0.26 *4*
209		6343.8	(30⁺)	6134.9	(29⁻)			
218.8 *1*	46 *2*	1340.85	7⁻	1122.04	6⁺	E1	0.0729	A_2=−0.21 *5*; A_4=+0.04 *4*; pol=+0.26 *3*
224		5363.5	(25⁺)	5139.4	(24⁻)			
233		6134.9	(29⁻)	5901.7	(28⁺)			
245.1 *2*		1038.32	5⁻	793.21	(3⁻)			
247		4835.5	(23⁺)	4588.3	22⁺			
267.3 *2*	22 *1*	1961.7	10⁺	1694.35	9⁻	E1	0.0457	A_2=−0.32 *4*; A_4=0.00 *6*; pol=+0.28 *5*
274		4391.6	(21⁺)	4117.7	20⁻			
281.4 *2*	15 *1*	2390.8	12⁺	2109.3	11⁻	E1	0.0407	A_2=−0.30 *6*; A_4=−0.05 *7*; pol=+0.29 *5*
291[f]		4682.6	22⁻	4391.6	(21⁺)			
297.3 *2*	21 *2*	1038.32	5⁻	741.10	4⁺	E1	0.0359	A_2=−0.37 *3*; A_4=+0.04 *4*; pol=+0.22 *4* POL for 297.3+299.3.
299.3 *2*	11 *3*	2825.5	14⁺	2526.3	13⁻	E1	0.0354	A_2=−0.17 *5*; A_4=+0.05 *7*; pol=+0.22 *4* POL for 299.3+297.3.
302.4 *2*	4 *1*	1340.85	7⁻	1038.32	5⁻	E2	0.1485	A_2=+0.26 *7*; A_4=−0.12 *9* Eγ: taken from 1992Wi14; 1982Fe04 report Eγ=303.0 *3*.
304		5139.4	(24⁻)	4835.5	(23⁺)			
310.6[a] *2*	7 *1*	2420.0	12⁻	2109.3	11⁻	(M1+E2)	0.4 *3*	A_2=−0.67 *7*; A_4=−0.06 *8*; pol=−0.24 *12*
312		4117.7	20⁻	3805.9	19⁻			
313		5901.7	(28⁺)	5588.1	27⁻			
318.7[#]	5 *1*	3285.1	16⁺	2966.4	15⁻			
331		3719.8	18⁻	3388.8	17⁻			
332.1[a] *3*	7 *1*	3719.8	18⁻	3387.7	16⁻	[E2]	0.1127	Eγ,Iγ: from 1982Fe04.
335		6678.8	(31⁻)	6343.8	(30⁺)			
337.5 *2*		2031.8	(10⁺)	1694.35	9⁻			
345[c]		5020.3	(24⁺)	4675.3	23⁻			
345[c]		5470.1	(26⁺)	5125.4	25⁻			
350.1 *2*		1896.8		1546.70	8⁺			
352.2 *1*	95 *5*	741.10	4⁺	388.90	2⁺	E2	0.0954	A_2=+0.24 *2*; A_4=−0.09 *3*; pol=+0.35 *4* A_2, A_4 and POL for 352.2+353.6.
353.6 *2*	21 *7*	1694.35	9⁻	1340.85	7⁻	E2	0.0943	A_2=+0.24 *2*; A_4=−0.09 *3*; pol=+0.35 *4* POL for 352.2+353.6.
367		3756.0	18⁺	3388.8	17⁻			
376		4588.3	22⁺	4212.6	21⁻			
380.9 *2*	71 *4*	1122.04	6⁺	741.10	4⁺	E2	0.0769	A_2=+0.24 *3*; A_4=−0.08 *4*; pol=+0.39 *8*
385[f]		4191.1?	(20⁺)	3805.9	19⁻			
388.9 *1*	100	388.90	2⁺	0.0	0⁺	E2	0.0727	A_2=+0.23 *3*; A_4=−0.08 *4*; pol=+0.34 *8*
397[f]		4588.3	22⁺	4191.1?	(20⁺)			
398		4117.7	20⁻	3719.8	18⁻			
404.3 *2*		793.21	(3⁻)	388.90	2⁺	D		$I_{(γ+ce)}$: ≥12 *7* from intensity balance at the 793.4 level; <8.6 from intensity balance at the

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^{208}Pb(^{13}C,3nγ),(^{14}C,4nγ),^{13}C(^{208}Pb,3nγ) 1989Sc33,1986Go21,1982Fe04 (continued)

γ(^{218}Ra) (continued)

E_γ [†‡]	I_γ [§]	E_i(level)	J_i^π	E_f	J_f^π	Mult. [&]	α [b]	Comments
								389.1 level. Mult.: ΔJ=1, dipole from γγ(θ)(DCO) (1992Wi14).
406.6 [@]	11 *2*	4212.6	21⁻	3805.9	19⁻			
410.6 *2*		2442.4	(10⁺)	2031.8	(10⁺)			
415.0 [e] *2*	8 [e] *2*	1961.7	10⁺	1546.70	8⁺	E2	0.0613	A_2=+0.13 *7*; A_4=−0.09 *8*; pol=+0.44 *8* A_2, A_4 for 415.0 doublet. POL for 415.0 doublet and 417.0.
415.0 [e] *2*	33 [e] *8*	2109.3	11⁻	1694.35	9⁻	E2	0.0613	A_2=+0.13 *7*; A_4=−0.09 *8*; pol=+0.44 *8* A_2, A_4 for 415.0 doublet. POL for 415.0 doublet and 417.0.
416.9 *2*	30 *8*	2526.3	13⁻	2109.3	11⁻	E2	0.0606	A_2=+0.36 *9*; A_4=−0.20 *10*; pol=+0.44 *8* POL for 416.9+415.0 doublet. E_γ,I_γ: doublet according to 1989Sc33. Part of the intensity of the 416.9 line belongs to 417γ from 3806 level.
417		3805.9	19⁻	3388.8	17⁻			I_γ: part of the intensity of the 416.9γ from 2526 level belongs to 417γ from 3806 level.
420.5 [@a]	8 *2*	3387.7	16⁻	2967.2	14⁻			
422.4 *2*	17 *6*	3388.8	17⁻	2966.4	15⁻	E2	0.0586	A_2=+0.26 *1*; A_4=−0.10 *9*; pol=+0.40 *9* POL for doublet.
424.6 *2*	22 *6*	1546.70	8⁺	1122.04	6⁺	E2	0.0578	A_2=+0.11 *6*; A_4=−0.15 *9*; pol=+0.40 *9* POL for 424.6+422.4.
429.3 *2*	5 *1*	2390.8	12⁺	1961.7	10⁺	E2	0.0562	A_2=+0.20 *7*; A_4=−0.05 *8*; pol=+0.46 *21*
432 [c]		5020.3	(24⁺)	4588.3	22⁺			
432 [c]		5901.7	(28⁺)	5470.1	(26⁺)			
434.8 [d] *2*	4 [d] *1*	2825.5	14⁺	2390.8	12⁺	E2	0.0544	A_2=+0.22 *8*; A_4=+0.04 *7*; pol=+0.44 *28* I_γ: Iγ=4 *1* is the measured intensity for the doublet.
434.8 [df] *2*	4 [d] *1*	4191.1?	(20⁺)	3756.0	18⁺			E_γ: placement proposed by the evaluators based on energy difference. I_γ: Iγ=4 *1* is the measured intensity for the doublet.
440.3 *2*	22 *1*	2966.4	15⁻	2526.3	13⁻	E2	0.0528	A_2=+0.14 *4*; A_4=+0.08 *11*; pol=+0.38 *11* E_γ: taken from 1992Wi14. 1982Fe04 report Eγ=439.6 *2*.
440.8 *2*		2967.2	14⁻	2526.3	13⁻			
442		6343.8	(30⁺)	5901.7	(28⁺)			
444		4835.5	(23⁺)	4391.6	(21⁺)			
450 [c]		5125.4	25⁻	4675.3	23⁻			
450 [c]		5470.1	(26⁺)	5020.3	(24⁺)			
457		5139.4	(24⁻)	4682.6	22⁻			
459.7 [#]	3 *1*	3285.1	16⁺	2825.5	14⁺			
462.7 *2*		1803.60		1340.85	7⁻			
462.7 [#]	8 *1*	4675.3	23⁻	4212.6	21⁻			
463		5588.1	27⁻	5125.4	25⁻			
464 [f]		5139.4	(24⁻)	4675.3	23⁻			
470		4682.6	22⁻	4212.6	21⁻			
471 [f]		3756.0	18⁺	3285.1	16⁺			
472.4 *2*		2328.3		1855.9				
503.9 *2*		2465.6		1961.7	10⁺			
528		5363.5	(25⁺)	4835.5	(23⁺)			

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^{208}Pb(^{13}C,3nγ),(^{14}C,4nγ),^{13}C(^{208}Pb,3nγ) 1989Sc33,1986Go21,1982Fe04 (continued)

γ(^{218}Ra) (continued)

E_γ [†‡]	I_γ [§]	E_i(level)	J_i^π	E_f	J_f^π	Mult.[&]	α [b]	Comments
534.7 2		1573.01		1038.32	5^-			
544		6678.8	(31^-)	6134.9	(29^-)			
547		6134.9	(29^-)	5588.1	27^-			
547.3[a] 2	10 1	2967.2	14^-	2420.0	12^-	E2	0.0313	A_2=+0.39 8; A_4=+0.05 8; pol=+0.44 8
565		4682.6	22^-	4117.7	20^-			
568.8 2		2465.6		1896.8				
681.6 2		1803.60		1122.04	6^+			
687.5 2		1725.8		1038.32	5^-			
733.9 2		1855.9		1122.04	6^+			
779.8 2		1573.01		793.21	(3^-)			
831.9 2		1573.01		741.10	4^+			
973.5 2		1714.60		741.10	4^+			

[†] From weighted average of 1992Wi14 and 1982Fe04 for levels up to 17^-, and above 17^-, values are from 1989Sc33, unless otherwise stated;

[‡] In addition to the γ rays listed here, 1983Ga11 suggest possible transitions with energies 324, 585, 683, and 734 feeding the 289 2^+ level, and a cascade of 547, 311, and 331 γ rays feeding the 2109 11^- level. These transitions and/or placements are not supported by later work, although 1992Wi14 place a 733.9 gamma from the 1856 level.

[§] Relative photon intensities from 1986Go21. See also 1982Fe04.

[&] From γ(θ) and γ(lin pol) data of 1982Fe04. Angular distribution/ correlation measurements are also reported by 1983Ga11, 1986Go21, 1989Sc33 and 1992Wi14, but no numerical values are given by these authors. In some cases multipolarities are from intensity balances.

[@] From 1986Go21, in coin with 423γ.

[#] From 1986Go21.

[a] The ordering of the 332-420-547-310 cascade is adopted from 1989Sc33. The ordering suggested by 1986Go21 was 420-332-311-547, and 332-306-547 by 1982Fe04.

[b] Total theoretical internal conversion coefficients, calculated using the BrIcc code (2008Ki07) with Frozen orbital approximation based on γ-ray energies, assigned multipolarities, and mixing ratios, unless otherwise specified.

[c] Multiply placed.

[d] Multiply placed with undivided intensity.

[e] Multiply placed with intensity suitably divided.

[f] Placement of transition in the level scheme is uncertain.

Adopted Levels, Gammas

Q(β^-)=−1520 *50*; S(n)=5930 *50*; S(p)=2340 *50*; Q(α)=9380 *50* 2017Wa10
S(2n)=13440 *50*, S(2p)=6710 *50* (2017Wa10).
Assignment: daughter of ^{222}Pa α decay (1970Bo13).
Theory references: consult NSR database (www.nndc.bnl.gov/nsr/) for 15 primary references for calculations of half-lives of radioactive decays, and two for nuclear structure.
Review of level data for nuclides with reflection asymmetry: 1996Bu45.

^{218}Ac Levels

Cross Reference (XREF) Flags

A ^{222}Pa α decay (4.1 ms)
B ^{209}Bi(^{12}C,3nγ)

E(level)[†]	J$^\pi$[‡]	$T_{1/2}$	XREF	Comments
0.0	(1$^-$)	1.03 μs *5*		%α=100 E(level): From ^{218}Ac α decay. Only the α-decay mode has been observed. Theoretical partial $T_{1/2}$=13.1 s for ^{218}Ac $\varepsilon+\beta^+$ decay (2019Mo01) gives %ε+%β^+=8×10^{-6}. J$^\pi$: from the systematics of odd-odd nuclides in this mass region, the probable configuration is $\pi h_{9/2}\otimes\nu g_{9/2}$, as proposed in ^{209}Bi(^{12}C,3nγ). $T_{1/2}$: from α decay. Weighted average of 0.98 μs *12* (2017Su18), 0.96 μs *5* (2015Kh09), 1.06 μs *9* (1989Mi17), 1.31 μs *12* (1989De06) and 1.12 μs *11* (1983Sc23). Others: 1.8 μs *1* (2019Mi08, from correlated α decays in ^{226}Np and ^{222}Pa decay chains, authors also give $T_{1/2}$=1.5 μs *1*); 0.27 μs *4* (1970Bo13) seem discrepant values. Note that statistics is poor in 2019Mi08.
0+x			B	E(level): see comment for ≈407−keV level.
122.5+x *2*			B	E(level): see comment for ≈529−keV level.
122.5+y[#]	(9$^-$)	32 ns *9*	B	%IT=100 E(level): y=x+z, where z is expected to be less than 100 keV. J$^\pi$: from the systematics of neighboring odd-odd nuclides, probable configuration=$\pi h_{9/2}\otimes\nu g_{9/2}$. $T_{1/2}$: from delayed component in (122.5γ)(total γ)(t) curve (1994De04). 1994De04 noted that mult(122.5γ)=M1 would give a much shorter half-life for 122.5+x level, and suggested one or more intermediate transitions of <100 keV from the (9$^-$) state to the 122.5+x level. 1994De04 also pointed out contribution from a prompt component in the (122.5γ)(total γ)(t) distribution, which may suggest population of the 122.5+x level by γ rays from higher levels of short half-lives. Half-life of 32 ns is assigned by the evaluators to the 122.5+y, (9$^-$) level, while noting that 1994De04 did not explicitly assign this half-life to the (9$^-$) or any other level, either in their level-scheme Fig. 2 or in the text of their paper. Occurrence of (1$^-$) ground states and (9$^-$) isomers in ^{216}Ac; and also in N=129 isotones ^{214}At and possibly in ^{212}Bi seem to support the assignment of (9$^-$) isomer in ^{218}Ac.
≈193			A	
226.90+y *24*	(9$^-$)		B	J$^\pi$: ΔJ=1, 189.2 M1 γ from 416.1+y (10$^-$) level.
≈407			A	E(level): this level may correspond to 0+x level from ^{209}Bi(^{12}C,3nγ) reaction.
416.10+y *14*	(10$^-$)		B	J$^\pi$: ΔJ=1, 293.6 (M1) γ to 122.5+y, (9$^-$) level; probable configuration=$(\pi h_{9/2}\otimes\nu i_{11/2})10^-\otimes 0^+$ core.
506.99+y[b] *13*	(11$^+$)	103 ns *11*	B	%IT=100 J$^\pi$: M2 γ to (9$^-$); (E1) γ to (10$^-$); possible bandhead. $T_{1/2}$: 384.5γ(t) in ^{209}Bi(^{12}C,3nγ).
≈529			A	E(level): this level may correspond to 122.5+x level from ^{209}Bi(^{12}C,3nγ) reaction which deexcites by 122.5γ.
≈560			A	

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Adopted Levels, Gammas (continued)

^{218}Ac Levels (continued)

E(level)[†]	J^{π}[‡]	XREF	Comments
≈580		A	
600.94+y *16*	(10⁻)	B	J^{π}: ΔJ=1, M1 γ to (9⁻). Possible configuration=($\pi h_{9/2}\nu g_{9/2}$)8⁻ ⊗ 2⁺ (unfavored). E(level): the ordering of the 81-478 cascade is not established experimentally, the ordering given here is preferred by 1994De04 from theoretical considerations.
630.38+y[#] *14*	(11⁻)	B	J^{π}: ΔJ=2, E2 γ to (9⁻).
681.98+y[a] *14*	(11⁺)	B	J^{π}: ΔJ=1, E1 γ to (10⁻); ΔJ=0, M1 γ to (11⁺).
789.16+y[@] *15*	(12⁺)	B	J^{π}: ΔJ=1, E1 γ to (11⁻); ΔJ=1, M1 γ to (11⁺).
990.45+y[&] *15*	(12⁻)	B	J^{π}: ΔJ=2, E2 γ to (10⁻); ΔJ=1 γ to (11⁺).
1044.89+y[b] *17*	(13⁺)	B	J^{π}: ΔJ=2, E2 γ to (11⁺).
1088.50+y[#] *17*	(13⁻)	B	J^{π}: ΔJ=2 γ to (11⁻); ΔJ=1, E1 γ to (12⁺).
1181.93+y[a] *17*	(13⁺)	B	J^{π}: ΔJ=2, E2 γ to (11⁺); (E1) γ to (12⁻).
1258.07+y[@] *19*	(14⁺)	B	J^{π}: ΔJ=2 γ to (12⁺); ΔJ=1, E1 γ to (13⁻).
1335.86+y[c] *22*	(14⁻)	B	J^{π}: ΔJ=1 γ to (13⁺).
1418.54+y[&] *17*	(14⁻)	B	J^{π}: ΔJ=2 γ to (12⁻); ΔJ=1, M1 γ to (13⁻).
1509.83+y[b] *19*	(15⁺)	B	J^{π}: ΔJ=2, E2 γ to (13⁺); ΔJ=1, (E1) γ to (14⁻).
1557.23+y[#] *19*	(15⁻)	B	J^{π}: ΔJ=2 γ to (13⁻); ΔJ=1, E1 γ to (14⁺).
1625.41+y[a] *19*	(15⁺)	B	J^{π}: ΔJ=2, E2 γ to (13⁺); ΔJ=1, (E1) γ to (14⁻).
1697.60+y[@] *23*	(16⁺)	B	J^{π}: ΔJ=2, E2 γ to (14⁺); ΔJ=1, E1 γ to (15⁻).
1789.45+y[&] *19*	(16⁻)	B	J^{π}: ΔJ=2, E2 γ to (14⁻); ΔJ=1, M1 γ to (15⁻).
1843.1+y[c] *3*	(16⁻)	B	J^{π}: ΔJ=1 γ to (15⁺);
1939.4+y[b] *3*	(17⁺)	B	J^{π}: ΔJ=2 γ to (15⁺); (E1) γ to (16⁻).
1990.2+y *3*	(17⁺)	B	J^{π}: ΔJ=1, E1 γ to (16⁻).
2025.8+y[a] *3*	(17⁺)	B	J^{π}: ΔJ=2 γ to (15⁺); possible γ to (16⁻).
2121.0+y[c] *4*	(18⁻)	B	J^{π}: γ to (16⁻); possible γ to (17⁺).
2141.0+y[@] *3*	(18⁺)	B	J^{π}: ΔJ=2 γ to (16⁺).
2239.6+y[b] *4*	(19⁺)	B	J^{π}: ΔJ=2 γ to (17⁺).
2630.2+y[@] *4*	(20⁺)	B	J^{π}: ΔJ=(2) γ to (18⁺).

[†] From least-squares fit to Eγ data.

[‡] All assignments are made from the γ-ray multipolarities, E1, E2, M1 branching ratios, and shell-model considerations and band associations. For high-spin (J>10) levels, ascending order of spins with excitation energy is assumed.

[#] Band(A): Band based on (9⁻), s=+1. Configuration=($\pi h_{9/2}\otimes\nu g_{9/2}$)⊗(0⁺,2⁺,..core).

[@] Band(a): Band based on (12⁺), s=+1. Configuration=($\pi h_{9/2}\otimes\nu g_{9/2}$)⊗(3⁻,5⁻,..core).

[&] Band(B): Band based on (12⁻), s=−1. Configuration=($\pi h_{9/2}\otimes\nu i_{11/2}$)⊗(0⁺,2⁺,..core).

[a] Band(b): Band based on (11⁺), s=−1. Configuration=($\pi h_{9/2}\otimes\nu i_{11/2}$)⊗(3⁻,5⁻,..core).

[b] Band(C): Band based on (11⁺), s=−1. Configuration=($\pi i_{13/2}\otimes\nu g_{9/2}$)⊗(0⁺,2⁺,..core).

[c] Band(c): Band based on (14⁻), s=−1. Configuration=($\pi i_{13/2}\otimes\nu g_{9/2}$)⊗(3⁻,5⁻,..core).

Adopted Levels, Gammas (continued)

$\gamma(^{218}Ac)$

E_i(level)	J^π_i	E_γ †	I_γ †	E_f	J^π_f	Mult. †	α ‡	Comments
122.5+x		122.5 *2*	100	0+x		M1	9.56	
122.5+y	(9⁻)	(z)		122.5+x				E_γ: z corresponds to either one or more gamma rays, with energy of <100 keV.
416.10+y	(10⁻)	189.2 *2*	100 *9*	226.90+y	(9⁻)	M1	2.79	
		293.6 *2*	24 *3*	122.5+y	(9⁻)	(M1)	0.820	
506.99+y	(11⁺)	91.0 *2*	85.3 *24*	416.10+y	(10⁻)	(E1)	0.1461 *23*	B(E1)(W.u.)=6.5×10^{-7} *8*
		384.5 *2*	100.0 *14*	122.5+y	(9⁻)	M2	1.201	B(M2)(W.u.)=0.31 *4*
600.94+y	(10⁻)	478.5 *2*	100	122.5+y	(9⁻)	M1	0.217	
630.38+y	(11⁻)	507.8 *2*	100	122.5+y	(9⁻)	E2	0.0392	
681.98+y	(11⁺)	81.1 *2*	24 *10*	600.94+y	(10⁻)	(E1)	0.198	
		175.0 *2*	26 *10*	506.99+y	(11⁺)	M1	3.48	
		265.8 *2*	100 *14*	416.10+y	(10⁻)	E1	0.0476	
789.16+y	(12⁺)	107.0 *2*	7.8 *22*	681.98+y	(11⁺)	(M1+E2)		
		158.8 *2*	100 *13*	630.38+y	(11⁻)	E1	0.1601	
		282.3 *2*	15 *4*	506.99+y	(11⁺)	M1	0.914	
990.45+y	(12⁻)	308.5 *2*	13.8 *25*	681.98+y	(11⁺)	D		
		360.0 *2*	2.9 *10*	630.38+y	(11⁻)	[M1]	0.469	
		574.3 *2*	100 *6*	416.10+y	(10⁻)	E2	0.0295	
1044.89+y	(13⁺)	537.9 *2*	100	506.99+y	(11⁺)	E2	0.0342	
1088.50+y	(13⁻)	299.3 *2*	100 *10*	789.16+y	(12⁺)	E1	0.0364	
		458.1 *2*	50 *4*	630.38+y	(11⁻)	Q		
1181.93+y	(13⁺)	137.0 *2*	3.3 *9*	1044.89+y	(13⁺)	[M1+E2]	4.8 *22*	
		191.4 *2*	74 *8*	990.45+y	(12⁻)	(E1)	0.1024	
		500.1 *2*	100 *7*	681.98+y	(11⁺)	E2	0.0406	
1258.07+y	(14⁺)	169.5 *2*	64 *4*	1088.50+y	(13⁻)	E1	0.1369	
		468.9 *2*	100 *11*	789.16+y	(12⁺)	Q		
1335.86+y	(14⁻)	291.0 *2*	100	1044.89+y	(13⁺)	D		
1418.54+y	(14⁻)	236.6 *2*	76 *5*	1181.93+y	(13⁺)	E1	0.0622	
		330.1 *2*	35 *4*	1088.50+y	(13⁻)	M1	0.595	
		373.5 *2*	8 *3*	1044.89+y	(13⁺)	D		
		428.1 *2*	100 *7*	990.45+y	(12⁻)	Q		
1509.83+y	(15⁺)	174.0 *2*	25 *5*	1335.86+y	(14⁻)	(E1)	0.1286	
		465.1 *2*	100 *6*	1044.89+y	(13⁺)	E2	0.0483	
1557.23+y	(15⁻)	299.1 *2*	100 *10*	1258.07+y	(14⁺)	E1	0.0364	
		468.7 *2*	36 *5*	1088.50+y	(13⁻)	Q		
1625.41+y	(15⁺)	115.6 *2*	6.5 *32*	1509.83+y	(15⁺)	[M1+E2]	8.4 *29*	
		206.8 *2*	90 *12*	1418.54+y	(14⁻)	(E1)	0.0853	
		443.5 *2*	100 *14*	1181.93+y	(13⁺)	E2	0.0544	
1697.60+y	(16⁺)	140.4 *2*	45 *4*	1557.23+y	(15⁻)	E1	0.215	
		439.5 *2*	100 *6*	1258.07+y	(14⁺)	E2	0.0556	
1789.45+y	(16⁻)	164.0 *2*	12.7 *10*	1625.41+y	(15⁺)	E1	0.1482	
		232.1 *2*	15.3 *13*	1557.23+y	(15⁻)	M1	1.574	
		279.8 *2*	100	1509.83+y	(15⁺)	(E1)	0.0423	
		370.9 *2*	100 *9*	1418.54+y	(14⁻)	E2	0.0868	
1843.1+y	(16⁻)	333.2 *2*	100 *18*	1509.83+y	(15⁺)	D		
		507.0§		1335.86+y	(14⁻)			E_γ: this γ is expected but not seen with certainty probably because it is obscured by strong 507.8γ.
1939.4+y	(17⁺)	96.2 *2*	48 *16*	1843.1+y	(16⁻)	(E1)	0.1262 *19*	
		429.6 *2*	100 *11*	1509.83+y	(15⁺)	Q		
1990.2+y	(17⁺)	200.7 *2*	100	1789.45+y	(16⁻)	E1	0.0915	
2025.8+y	(17⁺)	236.1§		1789.45+y	(16⁻)			
		400.4 *2*	100 *24*	1625.41+y	(15⁺)	Q		

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Adopted Levels, Gammas (continued)

$\gamma(^{218}Ac)$ (continued)

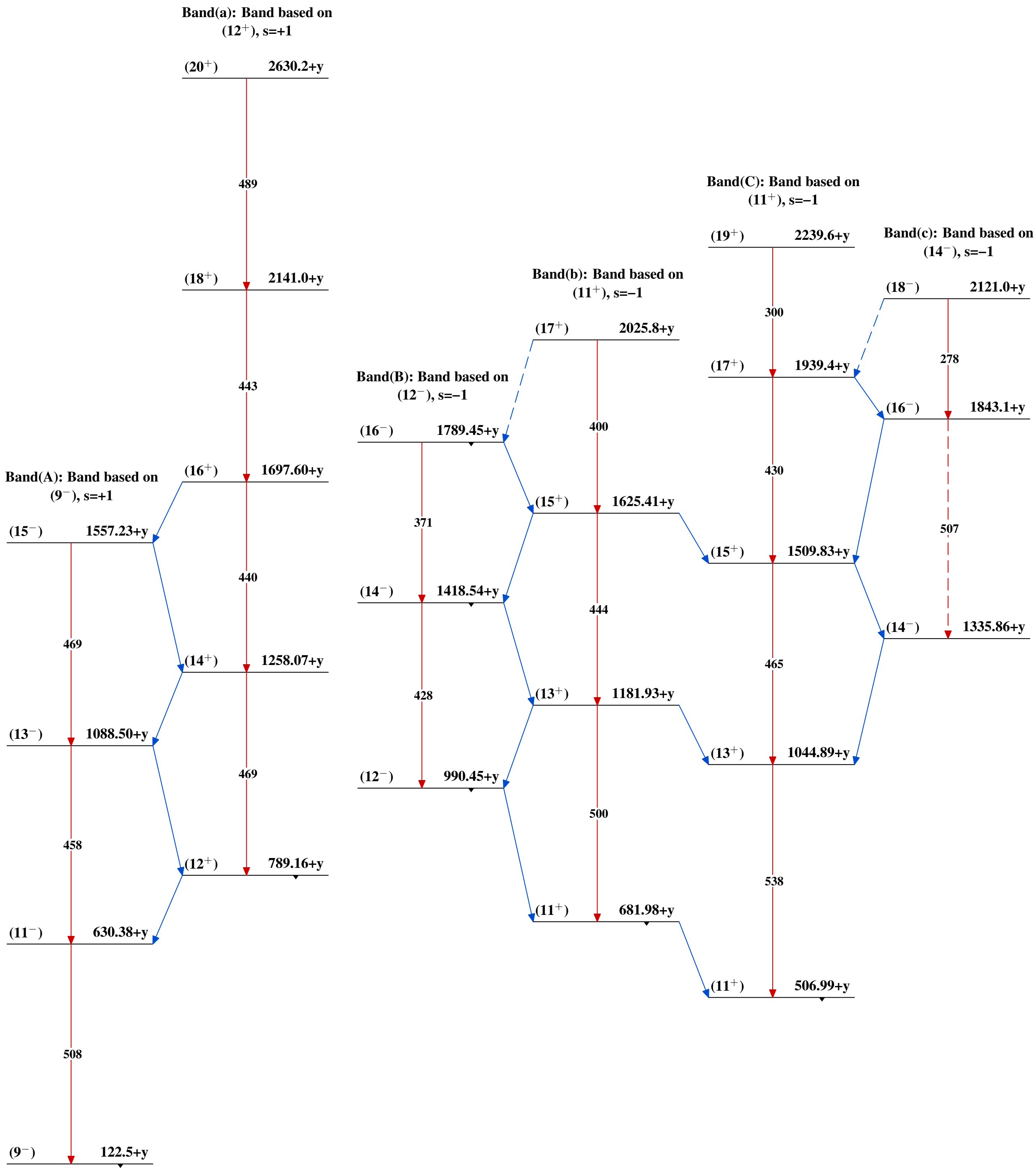
E_i(level)	J^π_i	E_γ †	I_γ †	E_f	J^π_f	Mult. †	α ‡
2121.0+y	(18⁻)	181.5§		1939.4+y	(17⁺)		
		277.9 *2*	100 *38*	1843.1+y	(16⁻)	[E2]	0.203
2141.0+y	(18⁺)	443.4 *2*	100	1697.60+y	(16⁺)	Q	
2239.6+y	(19⁺)	300.2 *2*	100	1939.4+y	(17⁺)	(Q)	
2630.2+y	(20⁺)	489.2 *2*	100	2141.0+y	(18⁺)	(Q)	

† From $^{209}Bi(^{12}C,3n\gamma)$.

‡ Total theoretical internal conversion coefficients, calculated using the BrIcc code (2008Ki07) with Frozen orbital approximation based on γ-ray energies, assigned multipolarities, and mixing ratios, unless otherwise specified.

§ Placement of transition in the level scheme is uncertain.

Adopted Levels, Gammas



$^{218}_{89}Ac_{129}$

^{222}Pa α decay (4.1 ms) 1970Bo13,1979Sc09,2019Mi08

Parent: ^{222}Pa: E=0.0; $T_{1/2}$=4.1 ms *6*; Q(α)=8890 *SY*; %α decay=100.0

^{222}Pa-$T_{1/2}$: Unweighted average of 4.5 ms *3* (2019Mi08, time correlations between ^{222}Pa fragments and subsequent α decays); 3.3 ms *3* (1995AnZY); 2.9 ms *+6−4* (1979Sc09); 5.7 ms *5* (1970Bo13). In ^{222}Pa Adopted Levels in the ENSDF database (March 2011 update), value is adopted from 1979Sc09.

^{222}Pa-Q(α): 8890 *50* (syst, 2017Wa10).

^{222}Pa-%α decay: Only α decay has been observed for the decay of ^{222}Pa. Theoretical partial $T_{1/2}$=21.3 s for ^{222}Pa ε decay (2019Mo01) gives %ε+%β^+=0.02.

1970Bo13: measured Eα, Iα, hindrance factors, half-life of decay of ^{222}Pa.

1979Sc09: measured Eα, half-life of decay of ^{222}Pa.

2019Mi08: ^{222}Pa activities obtained from the α-decay chains starting from ^{226}Np or in ^{181}Ta(^{48}Ca,X),E=212, 217, 226 MeV at the UNILAC accelerator of GSI facility. Evaporation residues (ERs) were separated by the SHIP velocity filter and implanted into the COMPAct Spectroscopy Set-up (COMPASS), consisting of silicon detectors. Measured energy and time spectra of correlations between ERs and α particles from subsequent decays; deduced Eα and half-lives of decays of ^{222}Pa and ^{218}Ac.

^{218}Ac Levels

E(level)[†]
(0.0)
≈193
≈407
≈529
≈560
≈580

[†] Level energies are deduced from Q(α)=8890 *50* (syst, 2017Wa10) and Eα values given here.

α radiations

Eα[†]	E(level)	Iα[‡&]	HF[#]	Comments
8160[@]	≈580	≈17[@]	≈16[@]	
8180[@]	≈560	≈17[@]	≈18[@]	
8210[@]	≈529	≈17[@]	≈22[@]	Iα(8210α+ 8180α+ 8160α)≈50 (1970Bo13). Other: 8.31 MeV *4* (2019Mi08), emitted from the decay of ^{222}Pa, only when the activity of ^{222}Pa is produced directly in a reaction, not from the ^{226}Np α-decay chain, which may suggest an isomer in ^{222}Pa.
8330	≈407	≈20	≈40	Eα: α peak is strongly mixed somewhat with 8.36 MeV-α line emitted by ^{214}Fr activity. Other: 8.47 MeV *4* (2019Mi08).
8540	≈193	≈30	≈105	Eα: α peak is mixed somewhat with α lines emitted by ^{214m}Fr activity. Other: 8.63 MeV *4* (2019Mi08).

[†] From 1970Bo13. Uncertainty is not given by the authors, but expected to be ≈20 keV, based on data for other isotopes in the paper. Only one α of 8210 keV was observed by 1979Sc09. In 2019Mi08, two main peaks were reported at 8.63 and 8.47 MeV, and a third one at 8.31 MeV. It appears that α energies are about 100 keV higher in 2019Mi08, as compared to those in 1970Bo13. Note that statistics are much weaker in 2019Mi08 as compared to those in 1970Bo13.

[‡] From 1970Bo13.

[#] r_0(^{218}Ac)=1.5515 *79*, obtained using r_0(^{218}Ra)=1.5571 *17*, r_0(^{216}Ra)=1.5664 *65*, r_0(^{220}Th)=1.5514 *30*, and r_0(^{218}Th)=1.529 *15*.

[@] Complex peak in 1970Bo13, too broad to be a single peak. Authors divide the peak in the three components. Total multiplet intensity ≈50 divided equally by the evaluators between the three α groups.

[&] Absolute intensity per 100 decays.

^{209}Bi(^{12}C,3nγ) 1994De04

1994De04 (also 1989De06): E=64-82 MeV. Measured Eγ, Iγ, γγ, ce, γ(θ), γγ(θ)(DCO), γγ(t). 1994De04 also studied (^{13}C,4nγ), but no data were given from this reaction.

^{218}Ac Levels

E(level)[†]	Jπ[‡]	$T_{1/2}$	Comments
0+x			
122.5+x *2*			
122.5+y[@]	(9⁻)[#]	32 ns *9*	E(level): y=x+z, where z is expected to be less than 100 keV. $T_{1/2}$: from delayed component in (122.5γ)(total γ)(t) curve (1994De04). 1994De04 noted that mult(122.5γ)=M1 would give a much shorter half-life for 122.5+x level, and suggested one or more intermediate transitions of <100 keV from the (9⁻) state to the 122.5+x level. 1994De04 also pointed out contribution from a prompt component in the (122.5γ)(total γ)(t) distribution, which may suggest population of the 122.5+x level by γ rays from higher levels of short half-lives. Half-life of 32 ns is assigned by the evaluators to the 122.5+y, (9⁻) level, while noting that 1994De04 did not explicitly assign this half-life to the (9⁻) or any other level, either in their level-scheme Fig. 2 or in the text of their paper.
226.90+y *24*	(9⁻)		
416.10+y *14*	(10⁻)		Configuration=($πh_{9/2}⊗νi_{11/2}$)10⁻ ⊗ 0⁺ core (1994De04).
506.99+y[c] *13*	(11⁺)	103 ns *11*	$T_{1/2}$: from 384.5γ(t) (1994De04).
600.94+y *16*	(10⁻)		E(level): the ordering of the 81-478 cascade is not established experimentally, the ordering given here is preferred by 1994De04 from theoretical considerations. Configuration=($πh_{9/2}⊗νg_{9/2}$)8⁻ ⊗ 2⁺ (unfavored).
630.38+y[@] *14*	(11⁻)		
681.98+y[b] *14*	(11⁺)		
789.16+y[&] *15*	(12⁺)		
990.45+y[a] *15*	(12⁻)		
1044.89+y[c] *17*	(13⁺)		
1088.50+y[@] *17*	(13⁻)		
1181.93+y[b] *17*	(13⁺)		
1258.07+y[&] *19*	(14⁺)		
1335.86+y[d] *22*	(14⁻)		
1418.54+y[a] *17*	(14⁻)		
1509.83+y[c] *19*	(15⁺)		
1557.23+y[@] *19*	(15⁻)		
1625.41+y[b] *19*	(15⁺)		
1697.60+y[&] *23*	(16⁺)		
1789.45+y[a] *19*	(16⁻)		
1843.1+y[d] *3*	(16⁻)		
1939.4+y[c] *3*	(17⁺)		
1990.2+y *3*	(17⁺)		
2025.8+y[b] *3*	(17⁺)		
2121.0+y[d] *4*	(18⁻)		
2141.0+y[&] *3*	(18⁺)		
2239.6+y[c] *4*	(19⁺)		
2630.2+y[&] *4*	(20⁺)		

† From least-squares fit to γ-ray energies.

‡ Spin, parity and approximate configurations (with only the strongest components given) are as proposed by 1994De04, based on γ multipolarities, E1, E2, and M1 branching ratios, and shell-model considerations. Since the spins of low-energy levels have not been determined, all the Jπ values are given in parentheses. The assignments are the same in the Adopted Levels. Note that all

Continued on next page (footnotes at end of table)

^{209}Bi(^{12}C,3nγ) 1994De04 (continued)

^{218}Ac Levels (continued)

the parities were assigned outside parentheses in the level-scheme Fig. 2 of 1994De04.
From the systematics of neighboring odd-odd nuclides, configuration=$\pi h_{9/2}\otimes\nu g_{9/2}$.
@ Band(A): Band based on (9$^-$), s=+1. Configuration=($\pi h_{9/2}\otimes\nu g_{9/2}$)⊗(0$^+$,2$^+$,..core).
& Band(a): Band based on (12$^+$), s=+1. Configuration=($\pi h_{9/2}\otimes\nu g_{9/2}$)⊗(3$^-$,5$^-$,..core).
[a] Band(B): Band based on (12$^-$), s=−1. Configuration=($\pi h_{9/2}\otimes\nu i_{11/2}$)⊗(0$^+$,2$^+$,..core).
[b] Band(b): Band based on (11$^+$), s=−1. Configuration=($\pi h_{9/2}\otimes\nu i_{11/2}$)⊗(3$^-$,5$^-$,..core).
[c] Band(C): Band based on (11$^+$), s=−1. Configuration=($\pi i_{13/2}\otimes\nu g_{9/2}$)⊗(0$^+$,2$^+$,..core).
[d] Band(c): Band based on (14$^-$), s=−1. Configuration=($\pi i_{13/2}\otimes\nu g_{9/2}$)⊗(3$^-$,5$^-$,..core).

γ(^{218}Ac)

E_γ	I_γ †	E_i(level)	J_i^π	E_f	J_f^π	Mult. ‡	α [a]	$I_{(\gamma+ce)}$	Comments
(z)		122.5+y	(9$^-$)	122.5+x					E_γ: z corresponds to either one or more gamma rays, with energy of <100 keV.
81.1# 2	10§ 4	681.98+y	(11$^+$)	600.94+y	(10$^-$)	(E1)&	0.198		
91.0 2	29.0§ 8	506.99+y	(11$^+$)	416.10+y	(10$^-$)	(E1)&	0.1461 23		
96.2 2	6.2§ 21	1939.4+y	(17$^+$)	1843.1+y	(16$^-$)	(E1)&	0.1262 19		
107.0 2	2.5§ 7	789.16+y	(12$^+$)	681.98+y	(11$^+$)	(M1+E2)&		39 11	$I_{(\gamma+ce)}$: listed in 1994De04. No ce data given for this transition, and since the γ energy is very close to the K-binding energy, the theoretical conversion coefficients are not reliable. Intensity balance at the 789.16+y level: [I(γ+ce)(107.0γ) + I(γ+ce)(158.8γ) + I(γ+ce)(282.3γ)] - [I(γ+ce)(468.9γ) + I(γ+ce)(299.3γ)] = −19 16.
115.6 2	0.8§ 4	1625.41+y	(15$^+$)	1509.83+y	(15$^+$)	[M1+E2]	8.4 29		
ˣ118.5 2	12.1 13					D			A_2=−0.40 15; DCO(D)=0.81 20
122.5 2	32.3 25	122.5+x		0+x		M1&	9.56		A_2=+0.04 8; DCO(Q)=1.24 23; α(L)exp=1.3 9
ˣ130.7 2	6.1 8								A_2=+0.36 15; DCO(D)=0.69 20
137.0 2	1.1§ 3	1181.93+y	(13$^+$)	1044.89+y	(13$^+$)	[M1+E2]&	4.8 22		DCO(Q)=0.72 20
140.4 2	15.1§ 13	1697.60+y	(16$^+$)	1557.23+y	(15$^-$)	E1	0.215		DCO(Q)=2.03 23; DCO(D)=0.91 13; α(L)exp<0.04 6
158.8 2	32§ 4	789.16+y	(12$^+$)	630.38+y	(11$^-$)	E1	0.1601		A_2=−0.19 14; DCO(Q)=1.80 16; DCO(D)=0.95 10; α(L)exp<0.07 6

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^{209}Bi(^{12}C,3nγ) 1994De04 (continued)

γ(^{218}Ac) (continued)

E_γ	I_γ[†]	E_i(level)	J^π_i	E_f	J^π_f	Mult.[‡]	α[a]	Comments
164.0 2	12.7[§] 10	1789.45+y	(16⁻)	1625.41+y	(15⁺)	E1	0.1482	A_2=−0.13 6; DCO(Q)=1.67 23; DCO(D)=0.92 14; α(L)exp=0.025 14
169.5 2	30.2 15	1258.07+y	(14⁺)	1088.50+y	(13⁻)	E1	0.1369	A_2=−0.24 8; DCO(Q)=1.77 12; DCO(D)=0.95 7; α(L)exp=0.07 4
174.0 2	8.4[§] 15	1509.83+y	(15⁺)	1335.86+y	(14⁻)	(E1)	0.1286	A_2=−0.25 14; DCO(Q)=1.7 3
175.0 2	11[§] 4	681.98+y	(11⁺)	506.99+y	(11⁺)	M1	3.48	A_2=+0.40 10; DCO(Q)=1.02 15; α(L)exp=0.5 2
181.5[@b]		2121.0+y	(18⁻)	1939.4+y	(17⁺)			From 277.9γ-96.2γ, Eγ=181.7 3.
189.2 2	37[§] 3	416.10+y	(10⁻)	226.90+y	(9⁻)	M1	2.79	A_2=−0.03 4; DCO(Q)=1.7 3; DCO(D)=0.87 16; α(L)exp=0.33 10
191.4 2	24.2[§] 25	1181.93+y	(13⁺)	990.45+y	(12⁻)	(E1)	0.1024	A_2=−0.29 8; DCO(Q)=1.93 25; DCO(D)=0.92 14
200.7 2	70 3	1990.2+y	(17⁺)	1789.45+y	(16⁻)	E1	0.0915	A_2=−0.14 6; DCO(Q)=1.84 14; α(L)exp<0.05
ˣ204.3 2	8.7 6					(E1)	0.0878	A_2=+0.10 6; DCO(D)=0.88 13
206.8 2	11.1[§] 14	1625.41+y	(15⁺)	1418.54+y	(14⁻)	(E1)	0.0853	A_2=−0.02 6; DCO(Q)=1.96 23; DCO(D)=1.06 14
232.1 2	7.2 6	1789.45+y	(16⁻)	1557.23+y	(15⁻)	M1	1.574	A_2=−0.60 14; DCO(Q)=2.5 3; DCO(D)=1.1 1; α(L12)exp=0.31 10
236.1[@b]		2025.8+y	(17⁺)	1789.45+y	(16⁻)			Eγ: this γ was probably obscured in the singles by the 236.6γ. From 400.4γ-164.0γ, Eγ=236.4 3.
236.6 2	24.3[§] 16	1418.54+y	(14⁻)	1181.93+y	(13⁺)	E1	0.0622	A_2=−0.18 8; DCO(Q)=1.83 15; DCO(D)=0.81 12; α(K)exp=0.06 3
265.8 2	42[§] 6	681.98+y	(11⁺)	416.10+y	(10⁻)	E1	0.0476	A_2=−0.15 5; DCO(Q)=1.86 18; α(K)exp<0.06 3; α(L)exp<0.009 6
277.9 2	1.3[§] 5	2121.0+y	(18⁻)	1843.1+y	(16⁻)	[E2]	0.203	
279.8 2	2.0 8	1789.45+y	(16⁻)	1509.83+y	(15⁺)	(E1)	0.0423	DCO(Q)=1.6 4 Mult.: from intensity balance (1994De04) at the 1509.83+y level.
282.3 2	4.8 11	789.16+y	(12⁺)	506.99+y	(11⁺)	M1	0.914	DCO(D)=1.15 20; α(K)exp=0.4 3
ˣ286.9 2	3.8 7							
291.0 2	11.1[§] 22	1335.86+y	(14⁻)	1044.89+y	(13⁺)	D		DCO(Q)=1.51 18; DCO(D)=1.06 12
293.6 2	9.0[§] 10	416.10+y	(10⁻)	122.5+y	(9⁻)	(M1)	0.820	DCO(D)=0.88 16
ˣ295.6 2	42[§] 4					D		A_2=−0.12 5; DCO(D)=0.94 11
299.1 2	40[§] 4	1557.23+y	(15⁻)	1258.07+y	(14⁺)	E1[&]	0.0364	A_2=−0.19 4; DCO(Q)=1.64 24; DCO(D)=1.00 10; α(K)exp=0.02 2 A_2, DCO and α(K)exp are for 299.3+299.1.
299.3 2	54[§] 5	1088.50+y	(13⁻)	789.16+y	(12⁺)	E1[&]	0.0364	A_2=−0.19 4; DCO(Q)=1.64 24; DCO(D)=1.00 10; α(K)exp=0.02 2 A_2, DCO and α(K)exp are for 299.3+299.1.
300.2 2	5.0 10	2239.6+y	(19⁺)	1939.4+y	(17⁺)	(Q)		DCO(Q)=0.75 16
308.5 2	5.6 10	990.45+y	(12⁻)	681.98+y	(11⁺)	D		DCO(Q)=1.8 2; DCO(D)=1.11 17 Uncertainty of 0.02 in DCO(Q) and 0.017 in DCO(D) in Table 1 of 1994De04 seem misprints.
ˣ325.2 2	20 4					D		A_2=−0.10 6; DCO(D)=1.00 15
330.1 2	11.2 13	1418.54+y	(14⁻)	1088.50+y	(13⁻)	M1	0.595	A_2=−0.28 8; DCO(Q)=2.5 5; DCO(D)=0.95 14; α(L12)exp=0.06 3
333.2 2	8.0 14	1843.1+y	(16⁻)	1509.83+y	(15⁺)	D		A_2=−0.18 11; DCO(Q)=2.3 5
ˣ333.5 2	32[§] 6							A_2=−0.30 5
ˣ342.0 2	3.8 23							

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^{209}Bi(^{12}C,3nγ) 1994De04 (continued)

γ(^{218}Ac) (continued)

E_γ	I_γ[†]	E_i(level)	J_i^π	E_f	J_f^π	Mult.[‡]	α[a]	Comments
360.0 *2*	1.2[§] *4*	990.45+y	(12⁻)	630.38+y	(11⁻)	[M1]	0.469	The intensity balance at the 990.45+y level is [I(γ+ce)(308.5γ)+I(γ+ce)(360.0γ)+I(γ+ce)(574.3γ)]-[I(γ+ce)(191.4γ)+I(γ+ce)(428.1γ)]=−11 *5*. Any E2 admixture would lower the conversion coefficient, and the intensity imbalance would become worse.
370.9 *2*	47[§] *4*	1789.45+y	(16⁻)	1418.54+y	(14⁻)	E2	0.0868	A_2=+0.31 *6*; DCO(Q)=0.95 *8*; DCO(D)=0.52 *6*; α(K)exp=0.07 *3* Mult.: E1 in Table 2 of 1994De04 is a misprint.
373.5 *2*	2.5 *10*	1418.54+y	(14⁻)	1044.89+y	(13⁺)	D		DCO(Q)=2.0 *4*
384.5 *2*	34 *3*	506.99+y	(11⁺)	122.5+y	(9⁻)	M2	1.201	A_2=−0.08 *8*; α(K)exp=0.9 *3*; α(L12)exp=0.29 *13*; α(M)exp=0.05 *3*
400.4 *2*	5.9 *14*	2025.8+y	(17⁺)	1625.41+y	(15⁺)	Q		DCO(Q)=1.24 *25*
428.1 *2*	32.0[§] *21*	1418.54+y	(14⁻)	990.45+y	(12⁻)	Q		A_2=+0.26 *5*; DCO(Q)=1.0 *1*
429.6 *2*	13.0[§] *14*	1939.4+y	(17⁺)	1509.83+y	(15⁺)	Q		A_2=+0.29 *8*; DCO(Q)=1.02 *11*
439.5 *2*	33.5 *21*	1697.60+y	(16⁺)	1258.07+y	(14⁺)	E2	0.0556	A_2=+0.17 *5*; DCO(Q)=0.93 *11*; DCO(D)=0.50 *6*; α(K)exp=0.030 *9*
443.4 *2*	24[§] *3*	2141.0+y	(18⁺)	1697.60+y	(16⁺)	Q		DCO(Q)=0.94 *12*; DCO(D)=0.53 *8*
443.5 *2*	12.4[§] *17*	1625.41+y	(15⁺)	1181.93+y	(13⁺)	E2	0.0544	DCO(Q)=0.84 *14*; DCO(D)=0.42 *7*; α(K)exp=0.05 *3* α(K)exp for 443.5+443.4.
458.1 *2*	27.2 *21*	1088.50+y	(13⁻)	630.38+y	(11⁻)	Q		A_2=+0.33 *7*; DCO(Q)=0.90 *13*; DCO(D)=0.58 *7*
465.1 *2*	33.0 *20*	1509.83+y	(15⁺)	1044.89+y	(13⁺)	E2	0.0483	A_2=+0.17 *4*; DCO(Q)=0.97 *13*; α(K)exp=0.020 *16*
468.7 *2*	14.4[§] *20*	1557.23+y	(15⁻)	1088.50+y	(13⁻)	Q		A_2=+0.23 *5*; DCO(D)=0.55 *6* A_2 and DCO are for 468.9+468.7.
468.9 *2*	47[§] *5*	1258.07+y	(14⁺)	789.16+y	(12⁺)	Q		A_2=+0.23 *5*; DCO(D)=0.55 *6* A_2 and DCO are for 468.9+468.7.
478.5[#] *2*	16[§] *4*	600.94+y	(10⁻)	122.5+y	(9⁻)	M1	0.217	DCO(Q)=1.18 *20*; α(K)exp=0.31 *9*; α(L12)exp=0.06 *2*
489.2 *2*	16.2 *17*	2630.2+y	(20⁺)	2141.0+y	(18⁺)	(Q)		A_2=+0.14 *8*
[x]492.9 *2*	14.6 *13*							A_2=+0.24 *7*; DCO(Q)=1.4 *3*
500.1 *2*	32.9[§] *21*	1181.93+y	(13⁺)	681.98+y	(11⁺)	E2	0.0406	A_2=+0.32 *5*; DCO(Q)=1.12 *14*; DCO(D)=0.58 *7*; α(K)exp=0.026 *10*
507.0[@b]		1843.1+y	(16⁻)	1335.86+y	(14⁻)			E_γ: this γ was probably obscured in the singles by the 507.8γ. From 333.2γ+174.0γ, E_γ=507.2 *3*.
507.8 *2*	83 *5*	630.38+y	(11⁻)	122.5+y	(9⁻)	E2	0.0392	A_2=+0.30 *5*; DCO(Q)=1.06 *13*; DCO(D)=0.52 *5*; α(K)exp=0.022 *7*
537.9 *2*	57 *5*	1044.89+y	(13⁺)	506.99+y	(11⁺)	E2	0.0342	A_2=+0.23 *4*; DCO(Q)=0.97 *10*; α(K)exp=0.030 *8*
574.3 *2*	40.7 *24*	990.45+y	(12⁻)	416.10+y	(10⁻)	E2	0.0295	A_2=+0.19 *5*; DCO(Q)=1.05 *10*; α(K)exp=0.04 *2*
[x]854.1 *2*	12.8 *14*							

[†] Measured by 1994De04 at E(^{12}C)=72 MeV bombarding energy.
[‡] Adopted by 1994De04 from their conversion electron and $\gamma\gamma(\theta)$ DCO-measurements.
[§] Intensities were deduced from coincidence data; the peaks were contaminated (1994De04).
[&] The electric/magnetic character is deduced from the intensity balance (1994De04).

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^{209}Bi(^{12}C,3nγ) 1994De04 (continued)

γ(^{218}Ac) (continued)

@ This transition is not listed in 1994De04; however, it is shown dashed on their level scheme, with a note that the line was not confirmed by $\gamma\gamma$ coincidences. Therefore, it is assumed that the γ is an expected transition, not seen.

The ordering of the 81-478 cascade is not established experimentally.

[a] Total theoretical internal conversion coefficients, calculated using the BrIcc code (2008Ki07) with Frozen orbital approximation based on γ-ray energies, assigned multipolarities, and mixing ratios, unless otherwise specified.

[b] Placement of transition in the level scheme is uncertain.

[x] γ ray not placed in level scheme.

Adopted Levels, Gammas

Q(β^-)=−6317 *21*; S(n)=7910 *15*; S(p)=3626 *15*; Q(α)=9849 *9* 2017Wa10
S(2n)=14074 *16*, S(2p)=5502 *14* (2017Wa10).
^{218}Th identified by 1973Hi06 in ^{209}Bi(^{14}N,5n) reaction and by 1973Ha32 in ^{206}Pb(^{16}O,4n), the two independent studies, 1973Hi06 published July 23, 1973, and 1973Ha32 on July 30, 1973.
Search for long-lived isomers: 2008La14 (no evidence found), 2007Ma57 (claimed evidence of presence of isomers).
Theory references: consult NSR database (www.nndc.bnl.gov/nsr/) for 47 primary references for calculations of half-lives of radioactive decays, 21 for nuclear structure, and four for nuclear reactions.

^{218}Th Levels

Cross Reference (XREF) Flags

A ^{222}U α decay (4.7 μs)
B ^{206}Pb(^{16}O,4nγ),^{209}Bi(^{14}N,5nγ)

E(level)†	J$^{\pi}$#	T$_{1/2}$	XREF	Comments
0.0@	0+	122 ns *5*	AB	%α=100 Only the α decay has been observed. Theoretical partial T$_{1/2}$>100 s for ^{218}Th ε+β^+ decay (2019Mo01) gives %ε+%β^+<1.2×10^{-7}. T$_{1/2}$: from decay curve for g.s. to g.s. 9666α. Weighted average (NRM) of 122 ns *8* (1973Ha32); 96 ns *7* (1973No09,1973Hi06); 125 ns *5* (1982Ch29); 0.16 μs *4* (2015Kh09); and 169 ns *+73−40* (2018Br13). Regular weighted average is 117 ns *7*, with reduced χ^2 of 3.7 as compared to critical χ^2=2.4. Weighted average is 125 ns *5* if the lowest value of 96 ns from 1973Hi06 is omitted.
689.6@ *6*	2+		B	J$^{\pi}$: E2 γ to 0+.
1194.2@ *9*	4+		B	J$^{\pi}$: E2 γ to 2+.
1563.9@ *11*	6+		B	J$^{\pi}$: E2 γ to 4+.
1765.8@ *12*	8+	1.2‡ ns *2*	B	J$^{\pi}$: E2 γ to 6+.
2104.0@ *14*	10+	0.25‡ ns *15*	B	J$^{\pi}$: E2 γ to 8+.

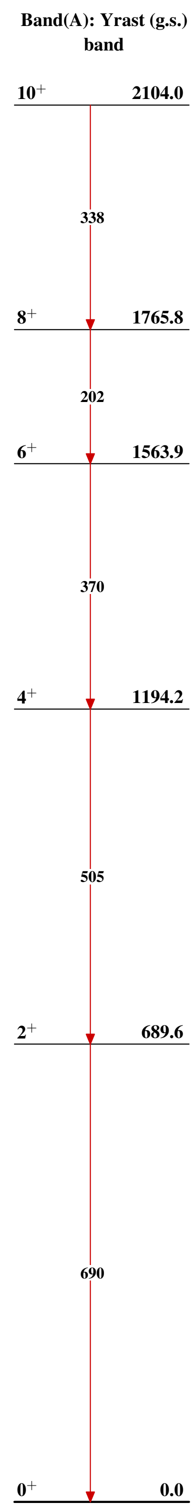
† From Eγ data.
‡ From ce(t) in ^{209}Bi(^{14}N,5nγ).
# From E2 cascade in g.s. yrast cascade.
@ Band(A): Yrast (g.s.) band.

γ(^{218}Th)

E$_i$(level)	J$^{\pi}_i$	E$_{\gamma}$†	I$_{\gamma}$†	E$_f$	J$^{\pi}_f$	Mult.†	α‡	Comments
689.6	2+	689.6 *6*	100	0.0	0+	E2	0.0209	
1194.2	4+	504.6 *6*	100	689.6	2+	E2	0.0418	
1563.9	6+	369.7 *6*	100	1194.2	4+	E2	0.0921	
1765.8	8+	201.9 *6*	100	1563.9	6+	E2	0.636 *12*	B(E2)(W.u.)=11.0 *19*
2104.0	10+	338.2 *6*	100	1765.8	8+	E2	0.1183 *18*	B(E2)(W.u.)=6 *+9−2*

† From ^{206}Pb(^{16}O,4nγ),^{209}Bi(^{14}N,5nγ).
‡ Total theoretical internal conversion coefficients, calculated using the BrIcc code (2008Ki07) with Frozen orbital approximation based on γ-ray energies, assigned multipolarities, and mixing ratios, unless otherwise specified.

Adopted Levels, Gammas



$^{218}_{90}Th_{128}$

^{222}U α decay (4.7 μs) 2015Kh09,1983Hi12

Parent: ^{222}U: E=0.0; $J^\pi=0^+$; $T_{1/2}$=4.7 μs *7*; Q(α)=9480 *50*; %α decay=100.0

^{222}U-$T_{1/2}$: From ^{222}U Adopted Levels in the ENSDF database (December 2015 update), where value is adopted from measurement by 2015Kh09.

^{222}U-Q(α): From 2017Wa10.

^{222}U-%α decay: Only α decay has been observed. Theoretical partial $T_{1/2}$=17.5 s for ^{222}U $\varepsilon+\beta^+$ decay (2019Mo01) gives $\%\varepsilon+\%\beta^+=2.7\times10^{-5}$.

2015Kh09: ^{222}U produced and identified in ^{176}Yb(^{50}Ti,4n), E(^{50}Ti)=231-255 MeV reaction. Evaporation residues (ER), separated by using gas-filled TransActinide Separator and Chemistry Apparatus (TASCA). Measured Eα, Iα, (ER)α correlated events from subsequent α-decay chains, half-lives of parent nuclei corresponding to the evaporation residues. The identification of ^{222}U was made based on observed (ER)α, two- or three-signal correlated events. A total of 81 ER traces were recorded for ^{222}U and analyzed with subsequent α decay chain: ^{222}U -> ^{218}Th -> ^{214}Ra. An α peak at 9.31 MeV *5* was observed in this work.

1983Hi12: W(^{40}Ar,xn) E=180 MeV; products were separated from the primary beam by the velocity filter; parent of ^{214}Ra (7.16-MeV α). An α group at 12.08 MeV was observed, and interpreted as the superposition of α rays from ^{222}U and the short-lived daughter ^{218}Th. One or both α particles were presumed to leave the detector before they deposited their full energy. Eα, therefore, could not be determined in this work.

^{218}Th Levels

E(level)	J^π	$T_{1/2}$	Comments
0	0^+	122 ns *5*	$T_{1/2}$: from Adopted Levels. 2015Kh09 measured 0.16 μs *4*, in agreement with the Adopted value, but the uncertainty is large.

α radiations

Eα	E(level)	Iα[‡]	HF[†]	Comments
9310 *50*	0	100	1.0	Eα: measured by 2015Kh09.

[†] The nuclear radius parameter r_0(^{218}Th)=1.529 *15* is deduced by assuming HF=1.0 for the ground-state to ground-state alpha decay branch.

[‡] Absolute intensity per 100 decays.

^{206}Pb(^{16}O,4nγ),^{209}Bi(^{14}N,5nγ) 1982Ch29,1985Bo32

1982Ch29: ^{206}Pb(^{16}O,4nγ) E=92 MeV. Measured Eγ, Iγ, αγ coin.
1985Bo32: ^{209}Bi(^{14}N,5nγ) E=91 MeV. Measured ce, (α)ce coin, K/L ratios.

^{218}Th Levels

E(level)	J^{π}†	$T_{1/2}$	Comments
0.0‡	0+		
689.6‡ *6*	2+		
1194.2‡ *9*	4+		
1563.9‡ *11*	6+		
1765.8‡ *12*	8+	1.2 ns *2*	$T_{1/2}$: 1.3 ns *4* (690ce(t)); 1.3 ns *3* (504ce(t)); 1.0 ns *2* (370ce(t)); 1.3 ns *1* (202ce(t)) (1985Bo32).
2104.0‡ *14*	10+	0.25 ns *15*	$T_{1/2}$: 338ce(t) (1985Bo32).

† From E2 cascade in g.s. yrast cascade. The assignments are the same in Adopted Levels.
‡ Band(A): Yrast band.

γ(^{218}Th)

Eγ†	Iγ‡	E_i(level)	J^{π}_i	E_f	J^{π}_f	Mult.§	α#	Comments
ˣ146.9& *10*	4 *2*							
ˣ173.3& *6*	44 *4*							
201.9 *6*	37 *4*	1765.8	8+	1563.9	6+	E2	0.636 *12*	K/L=0.45 (1985Bo32) I(ce)=300 *26* (1985Bo32).
338.2 *6*	57 *8*	2104.0	10+	1765.8	8+	E2	0.1183 *18*	K/L=1.0 *3* (1985Bo32) I(ce)=150 *30* (1985Bo32).
ˣ355.0@						D	0.28 *25*	K/L=7 *3* (1985Bo32) K/L(theory)=5.45 *12* for E1, 5.33 *12* for M1, and 1.39 *3* for E2. I(ce)=26 *21* (1985Bo32). Iγ: I(γ+ce)(355γ)/I(γ+ce)(689.6γ)<1.0 (1985Bo32).
369.7 *6*	80 *9*	1563.9	6+	1194.2	4+	E2	0.0921	K/L=1.5 (1985Bo32) I(ce)=81 *26* (1985Bo32).
ˣ390.5& *10*	19 *6*							
ˣ414.5& *10*	25 *8*							
504.6 *6*	98 *15*	1194.2	4+	689.6	2+	E2	0.0418	K/L=2.5 *5* (1985Bo32) I(ce)=21 *5* (1985Bo32).
689.6 *6*	100 *17*	689.6	2+	0.0	0+	E2	0.0209	K/L=4 *1* (1985Bo32) I(ce)=16 *5* (1985Bo32). Mult.: E2 or M2 from measured K/L ratio; M2 is highly unlikely as there is no evidence for long lifetime of 689.6 level.

† Average of values from 1982Ch29 (γ data) and 1985Bo32 (ce data), unless otherwise stated.
‡ From 1982Ch29. Conversion electron intensities are available from 1985Bo32.
§ From K/L measurements by 1985Bo32. The K/L values listed here have been read (by evaluators) from Figure 4 of 1985Bo32.
& Observed only by 1982Ch29.
@ Observed only by 1985Bo32.
# Total theoretical internal conversion coefficients, calculated using the BrIcc code (2008Ki07) with Frozen orbital approximation based on γ-ray energies, assigned multipolarities, and mixing ratios, unless otherwise specified.
ˣ γ ray not placed in level scheme.

Adopted Levels

Q(β^-)=−3211 *23*; S(n)=6456 *24*; S(p)=811 *21*; Q(α)=9815 *10* 2017Wa10
S(2n)=15260 *60*, S(2p)=4039 *21*, Q(εp)=2691 *22* (2017Wa10).
1979Sc09: ^{218}Pa produced and identified in ^{181}Ta(^{40}Ar,xn) reaction, measured excitation function.
2000He17 (also 1996An21): ^{170}Er(^{50}Ti,X),E=150-211 MeV; measured $T_{1/2}$.
1999Bo52: measured yield in ^{197}Au(^{26}Mg,X),E<164 MeV.
2001Ni06: measured yield in Ce(^{82}Se,X).
2005Li17: measured yield in ^{9}Be(^{238}U,X).
Theory references: consult NSR database (www.nndc.bnl.gov/nsr/) for eight primary references for calculations of half-lives of radioactive decays, and two for nuclear structure.

^{218}Pa Levels

E(level)	$T_{1/2}$	Comments
0	113 μs *10*	%α=100 Only the α decay has been observed. Theoretical partial $T_{1/2}$=57.4 s for ^{218}Pa $\varepsilon+\beta^+$ decay (2019Mo01) gives %ε+%β^+=2×10^{-4}. E(level): the observed activity is assumed to correspond to the g.s. of ^{218}Pa. $T_{1/2}$: from 2000He17. Other: 0.12 ms *+4−2* (1979Sc09). Weighted average of the two values is 114 μs *10*.

Adopted Levels

S(n)=9150 *SY*; S(p)=2463 *21*; Q(α)=8775 *9* 2017Wa10

S(2n)=17310 *30*, S(2p)=2982 *18*, Q(εp)=2400 *17* (2017Wa10).

^{218}U produced in ^{197}Au(^{27}Al,6n), and identified as parent of ^{214}Th (1992An04). 1997SaZQ reported a cross section of 1.7 nb *12* at E=161 MeV for this reaction.

2007Le14 (also 2005Le42): ^{218}U produced in ^{182}W(^{40}Ar,4n),E=186 MeV; fusion products were separated from beam particles with the RITU gas-filled separator and implanted into the DSSD of the GREAT spectrometer at the RITU focal plane. Measured half-lives of g.s. and an isomer.

2015Ma37: ^{218}U produced and identified in ^{182}W(^{40}Ar,4n), E(^{40}Ar)=189.5 MeV using the Sector-Focusing cyclotron facility at HIRFL-Lanzhou. The evaporation residues (ERs) were separated from the incident beam particles using gas-filled recoil separator for heavy ions (SHANS). Measured Eα, (residues)$\alpha_1\alpha_2$ correlations, where α_1 is from parent nucleus and α_2 from daughter nucleus, half-lives. The residues and α particles were detected by using multiwire proportional gas counter (MWPC) and position-sensitive silicon strip detectors (PSSD).

Theory references: consult NSR database (www.nndc.bnl.gov/nsr/) for 26 primary references for calculations of half-lives of radioactive decays, and 13 for nuclear structure.

^{218}U Levels

E(level)	J^π	$T_{1/2}$	Comments
0.0	0^+	0.51 ms *+17−10*	%α=100 %α: only the α decay, E(α)=8612 *9* (2007Le14,2005Le42) has been observed. Theoretical partial $T_{1/2}$ for ε+β^+ decay=15.4 s (2019Mo01) gives %ε+%β^+=0.003. $T_{1/2}$: from 2007Le14 (also 2005Le42). Others: 1.5 ms *+73−7* (1992An04), 1.15 ms *+158−42* (2015Ma37, from (implants)α-correlations).
2105 *19*	(8^+)	0.56 ms *+26−14*	%α=?; %IT=? Only α decay has been observed with Eα=10678 *17* (2007Le14,2005Le42). E(level): from difference of Q(α) values from isomer and g.s. decay, assuming the isomer decays directly to the ^{214}Th g.s. through an L=8 transition. $T_{1/2}$: from 2007Le14 (also 2005Le42). Other: 0.28 ms *+130−12* (2015Ma37, from (implants)α-correlations). Weighted average of the two values is the same as from 2007Le14. J^π: from 2007Le14 (also 2005Le42) based on comparison with ^{216}Th, (8^+) isomer and expected similar structures of ^{216}Th and ^{218}U. Proposed configuration=$\pi h_{9/2}\otimes\pi f_{7/2}$.

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